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AUSTRALIAN INSTITUTE OF AGRICULTURAL SCIENCE

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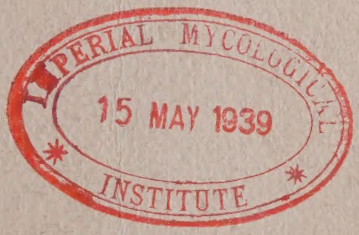

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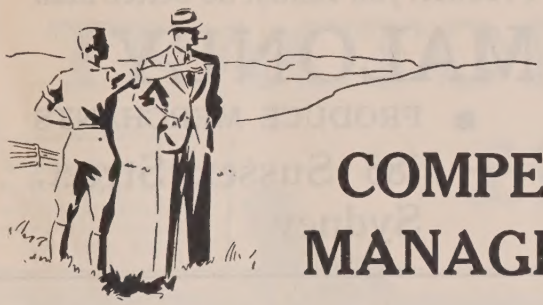

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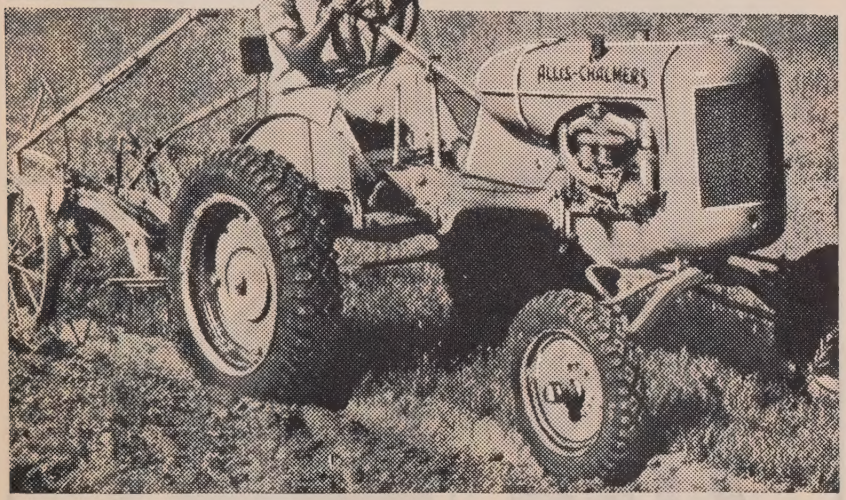

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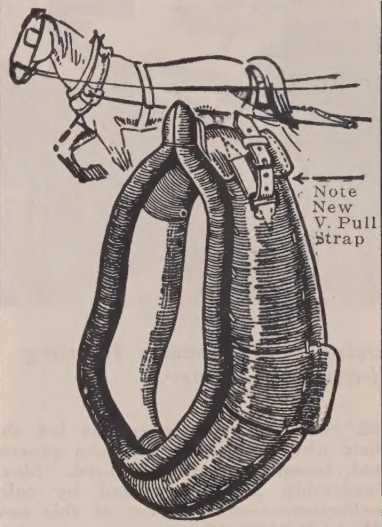

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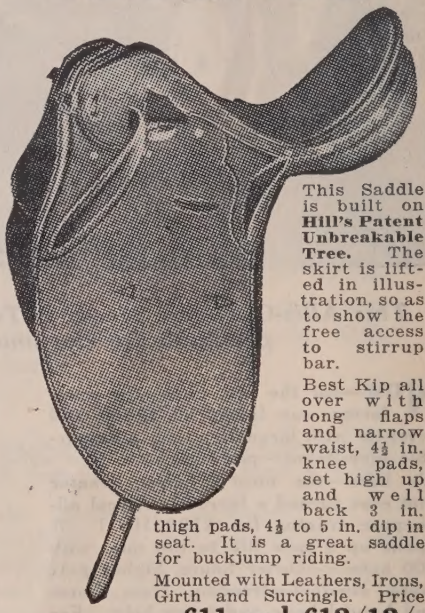

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"Whither Are We Going?"

What solution has science to offer for the maladjustments in present-day society and in international relations? This burning question continues to exercise the minds of leaders in science, particularly in Great Britain and the United States, and the latest news from abroad tells of the co-operative efforts being undertaken on this vital problem by the British and American Associations for the Advancement of Science. For some time past it has scarcely been possible to peruse overseas news in such journals as *Nature* and *Science* without appreciating the significance of the tremendous impact scientific achievement has made upon civilization generally, and it has now become almost platitudinous to state that while science has provided us with all manner of amenities, it has at the same time led to an order in which social dislocations and economic disparities are the unhappy result—an order in which international crises are feared because of the ghastly instruments

of destruction and mass murder now at a nation's disposal. It is a sad reflection on our civilized state that with all the improvements and advances made possible through scientific effort, there still exist those problems of maldistribution of wealth, unemployment and "bulging granaries with no buyers, yet many hungry". The problem of the farmer today is not so much how to increase crop yields or cope with pests and disease, but how to secure a satisfactory return for his farm produce. Indeed, questions of soil fertility, plant protection and so forth, much as they need further study, pale into insignificance alongside the pressing complexities of economic adjustment. As Dr. H. C. Wilson, of Florida, stated recently: "The farmer today is a rural entrepreneur whose factory is a tract of land. Scientific management and the applications of technology make this sort of factory farming highly efficient as a producing enterprise, but with this increased efficiency has come an easy susceptibility to every ill that occurs anywhere in the economic order." This social revolution, however, is apparent in all spheres of modern life throughout the world, and it is with this full realization that the British and American Associations are co-operating to ascertain ways and means of effecting a solution. The A.N.Z.A.A.S. at its meeting in Canberra in January devoted a special session to a discussion on "Science and Society", but the contributions were disappointing in that they offered little more than a re-statement of the position as at present understood. Sir David Rivett suggested that the main way by which scientific men in Australia could use their weight in relation to the problem was by getting right into the legislative and administrative arenas, while Professor Vonwiller considered that scientists should take steps to ensure that governing bodies consisted largely of people educated to understand the possibilities and limitations of scientific effort, and trained to apply the essentials of scientific method in the attack on problems of society. Sir John Russell's view that a satisfactory solution would result only when those concerned with life and moral problems—men of science and men of religion—were brought together, is one that is now receiving consideration in various quarters. While the approach to the problem is admitted to involve (*a*) education to provide everybody (scientists included) with a clearer understanding of social and scientific processes, and (*b*) development of the social sciences so as to give a better understanding of man in relation to his fellows, the trend of opinion is not without regard to the importance of developing refinements in our ethical code. In his address before the American Association last December, Sir Richard Gregory showed that in the study of man and society from the earliest ages it is seen that faith in an unseen power which lies behind the appearance of things is a fundamental component of man's nature, and in this Sir Richard sees "the guide pointing the way to an enlargement of the ethical ideal in which present differences and antagonisms may be resolved".

Presidential Address

AGRICULTURAL SYSTEMS

WITH SPECIAL REFERENCE TO THE AUSTRALIAN COUNTRYSIDE

By

S. M. Wadham, M.A., Dip.Agr.,
Professor of Agriculture, University of Melbourne, Vic.

(*Delivered to the Australian Institute of Agricultural Science at its Second General Meeting, held in Canberra, A.C.T., on January 9, 1939.*)

At the outset of this address, it is my obvious duty to apologize humbly to the Institute for my absence from its most important meeting during my tenure of office as President. Unfortunately, it was imperative that I should be in Britain early in 1939, and there was no alternative but to crave the pardon of members and arrange for this address to be delivered other than by myself. I am very appreciative of Mr. Leeper's kindness in agreeing to read it for me.

I make no apology whatever for choosing a subject which is not scientific in the strict sense of the term. I hold the view that there is always a grave danger that members of scientific bodies will focus their mind too closely on their own immediate problems, and not pay enough attention to the greater problems of the outside world on which the results of their own efforts may have much influence and of which they are, after all, members. In the pure sciences this danger has now been realized, and both in Europe and America scientific bodies are beginning to make a serious examination of the results of recent discoveries on the general structure of society and the welfare of mankind. Fortunately, for some years, agricultural science has realized the importance of admitting certain of the social sciences, notably economics, within its boundaries, and although in Australia the subject has never received anything like the attention it deserves, one may hope that such a state of affairs will not continue indefinitely. In my opinion at least, the agricultural scientist who has a sound consciousness of the national, economic and sociological background of the countryside for which he is working, is generally a more useful member of society than if he is a specialist pure and simple (using those adjectives in either of their usual significances). Paradoxical as it may be, detachment and specialist studies by themselves seem to me to lead the human mind to paths which are ultimately irrational from the immediate

practical standpoint of the human race. The world at large accepts my view when it draws the familiar picture of a professor as a bearded and bespectacled gentleman with little sense of the human side of his or any other subject. The congeries of subjects which we enfold under the title of Agricultural Science should be kept in close touch with the real world if we are to be of maximum assistance to humanity at large.

This viewpoint seems most important in Australia for three related reasons: firstly, because ours is a country in which social and economic experiments at maintaining agricultural stability are common and it is possible that they may at times be carried on at too high a price; secondly, because this Institute, having become a responsible body, is gradually developing a standing from which it may expect to speak authoritatively on numerous questions; and thirdly, this present time seems to be one of the periods of major upheaval in the world's history. Whether the changes which we are witnessing can be compared adequately with those which occurred during the decline of the Roman Empire or whether they should rather be regarded as a specially active phase of the Industrial Revolution, time will show; whichever comparison is the more accurate, they are of profound significance to agriculture, and especially to the agriculture of countries concerned with the export of primary products.

The agricultural systems of the world are innumerable. They vary from the simple "extensive" grazing on a Queensland cattle station in a dry district to the complicated organization of a mixed farm in Europe where dairy products including pigs and some young stock and poultry are sold, and the farm produces grass, hay, and silage, also grain and forage crops for its own stock, while some grain and possibly vegetables may also be raised for the market; straw is conserved and all animal wastes are returned to the soil in the form of farmyard manure. Many of these systems are transitory, others are permanent for long periods of time. Change may be either progressive or retrogressive. In the former case, the land is put to greater use and made more productive under the new system than it was under the one which preceded it—as when a sheep station is subdivided into farms providing wheat, wool and fat lambs. In the latter, the more intensive system is abandoned for a type of husbandry which is satisfied with a low rate of production, as when farms on which pastures have been well maintained are allowed to go back, and their productivity falls to the level of what can be produced under a purely exploitative system of management. In no case can a system be really permanent if it fails to ensure the maintenance of the general level of fertility of the soils it uses.

Although many of us like to think of a stable, organized arrangement of the farming industries of our countryside, it is essential to realize that

changes are taking place all the time. Scientific discovery is in itself the main cause of progressive changes in agricultural systems. Each new discovery of a major order gives man greater control over the environment or over the plants, animals or materials of the farm and makes it possible for him to obtain a greater efficiency in his methods. Paradoxically, scientific discovery may lead to retrogressive changes for secondary reasons. Wheat used to be grown on mixed farms in scattered areas in the Western District of Victoria and abundantly in Tasmania at the middle of last century. The development of the present wheat belt in Victoria and New South Wales in the 'eighties' and 'nineties' owing to railway facilities and discoveries of various kinds, including those of Farrer, lowered costs of production to such an extent that wheat farming in the older areas was unable to compete and largely gave way to a system with a lower level of production. If some new discovery enables men to grow, let us say, carrots more effectively than heretofore, then marginal producers of carrots under the older system have to change over to some other form of production; the change may be retrogressive from their point of view, but the discovery is valuable to the nation as a whole because it is, or should be, able to obtain its necessary supplies of carrots at a lower price.

I take it that we are all anxious to improve man's control over agricultural processes, and therefore we are happy about progressive changes; those of the retrogressive order worry us; yet at times they are inevitable and man's obstinate refusal to recognize the need for them may lead to considerable monetary loss and discouragement to individuals; further, national assistance is at times invoked in the attempt to maintain agricultural systems which should be allowed to pass into the limbo of things forgotten—or perhaps I should say, into the the archives of the agricultural historian. We in Australia are used to the invocation of Government assistance for the purpose of helping indigent rural industries; at times such assistance, which obviously weakens the general body politic, may merely serve to perpetuate unsatisfactory and outmoded systems of farming. I do not know, but I suggest it is possible that the attempt to maintain whole milk production on certain "historic" areas adjacent to capital cities, when more efficient and cheaper supplies might be obtained from more remote districts now that transport is more efficient, may be a case in point.

Survey of Agricultural Systems in Great Britain.

I have thought that it would be of some interest to make a general survey of the progress of agriculture in Great Britain and up to the present day, partly because we are naturally somewhat more interested in England than in any other country except Australia, and because, as we shall see, the forms of land ownership and occupation act as definite factors in

agricultural stability; and Australian systems are, to a certain extent, based on the British types. Also, I believe we can discern certain general tendencies in the evolution of agricultural systems, and having discerned them, we can examine the present systems in Australia and decide where they lie in reference to a general sequence.

Authorities are somewhat divided as to the details of the actual form of the earliest English agriculture. It seems clear that in Saxon times the exploitation of the land took a very simple form, which has been described as "wild field grass" husbandry. Under this system the inhabitants of the various villages worked together in a communal way. The fields were open and were either cultivated land or pasturage. The same areas were retained in the same condition all the time.

The system was one of exploitation in its extreme form. Cereals alone were cultivated, and the soil naturally became exhausted after a few years. When this happened a fresh area of land was cleared and broken down for cropping, and so in time the tracts which had been used for cultivation spread. It is of some interest to note that from the point of view of the soil itself, this system of husbandry is not far removed from that which prevailed in the early days of the present wheat belt in Australia before the introduction of superphosphate, while the treatment of the grazing land was identical with that which is carried out over millions of acres in the Commonwealth. The difference between the climate in the two countries is of considerable significance, but I think it is inescapable that such methods of land utilization must, in the long run, lead to a steady degradation of soil fertility—a degradation which will vary in rate according both to the climate and the amount of general foodstuffs stored in the soil and to the rate of stocking, but it will take place sooner or later nevertheless.

Starting from this simple system, the first major change in British agriculture was due to the Norman Conquest and the consequent alteration in the social structure of the nation. The Normans introduced the manorial system, which was probably Roman in origin. Under it, the land was divided into the fields belonging to the manor and the fields held by the general population of the district who had been forced into a position of servitude. The peasants paid rent, partly in kind and partly in service. In addition to the cultivated areas there was again common grazing land used by the stock of both the manor and the serfs, all parties having well-defined rights as to the number of head they might graze. A manorial court, at which the Lord of the Manor or his representative presided, was held at stated intervals. At these courts duties were allotted to various members of the community and the land and the grazing rights were allocated; penalties were also imposed on those who had failed in their agricultural duties. The system of agriculture was as crude as that which had preceded it; because,

on the one hand, there was no method of improving the grazing on most commons, and there was little chance of raising the productivity of the pasturage above a meagre level. On the other hand, the crop fields were divided into strips separated by banks or paths. As the strips were usually allocated by lot and each man had several of them often widely spaced from one another, it was difficult to manage them well; further, the paths were an excellent seeding ground for various weeds which spread to the strips. A system of rotation had appeared and in most communities there were three arable fields, one of which was put under a winter cereal such as wheat, while a second was cropped to spring cereals such as barley or oats, and the third was fallowed. There was thus little opportunity of improving fertility. This is similar in some ways to the cropping system which prevails today in many parts of the wheat belt of Australia, the only difference being that in most districts we have recognized the need for superphosphate and some sheep are often carried as part of normal practice. The manorial system fitted the social order of the day and provided the labour for the manor and also a living of a sort for the working peasant. Yields were apparently very low—as we would recognize was inevitable after years of exploitation under such a system of management. The only return of manurial constituents to the soil was through the grazing of the stubble after the season of harvest. It seems clear that there was considerable population pressure on the land at that time, and want and famine were waiting on the doorstep every spring. In passing it is of interest to note that a somewhat similar system applied in certain parts of Russia until the opening of the present century.

Catastrophe, in the form of the Great Plague known as the Black Death, was the immediate cause of the destruction of the manorial system. This plague, which swept away half the population of many districts in the year 1349, seems to have done two things. In the first place it eased the pressure on the productivity of the soil by diminishing the population, and in the second place it created such a scarcity of man power that the value of labour went up in both towns and villages and the peasants were able to move about more freely and demand better conditions of service. It is interesting to reflect that even in that long-distant day the labour factor could be of major significance in the agricultural system. As a result of the Black Death, the lords of the manor found it more expedient to let land for a money rent than on a basis of service. About this time the woollen industry began to take a leading place in the economic life of the country and sheep keeping became particularly advantageous. This economic change was also an important factor in the break-up of the old system because the landlords found that they could run flocks in enclosed fields much more effectively than on the open common.

However, many of the commons were retained under a modified system for many years, but it was again population pressure creating a demand for food which caused the next wave of enclosure four centuries later.

During the period 1400 to 1750, a good many changes took place in agricultural methods, some major, some minor in character. Most of these, however, remained more or less localized. Some diversification in the cropping appeared, more peas and beans were grown in appropriate districts, lucerne was cultivated and clovers were also occasionally encouraged. Such crops as cabbages, carrots and particularly turnips, were in places transferred from the garden to the field scale. The potato did not, however, manage to reach this status during that period. The system of tillage was improved, horses came into use as draught animals for the farm, although oxen were still often employed. The drill was invented in 1701. Much new knowledge was stored up in various localities. The old system of 'open field farming' continued to exist except where enclosed farms had been created.

Meanwhile the population had begun to increase rapidly. It seems to have increased by 80 per cent. in the course of the 18th century. The industrial revolution was beginning, food consumption was increasing, and as this was a period of intense international hostility importations were often uncertain. This situation was used as the basis of political argument for the extinction of the "commons" system of land tenure, and most of the country became divided into farms in the accepted sense of the word. It was in the period 1750 to 1814 that a broad scale advance was made in the agricultural system of the country, largely consequent upon this change in the system of land tenure. Many advances were made by practical farmers in every direction. All classes of stock were improved. New machines were invented and gradually came into wide use. Manurial practice developed. The potato began to take its place as a crop. Rotations became definite, and the pen of Arthur Young introduced the new knowledge into regions far and wide. Yields improved, agriculture prospered and prices still rose during the period of the Napoleonic war. The system which was built up may be described as the beginning of intensification; its mainspring lay in the economic circumstances of the times and its component parts were fashioned by the go-ahead farmers whose names are enshrined in history—Coke the agriculturist, "Turnip" Townsend, Bakewell the breeder, Tull the man with the drill and the horse hoe, while Arthur Young filled the role of chief advertising agent.

In some ways this system of British agriculture seems to me to be comparable with that which was developed in the strictly agricultural parts of Australia up to 1928. At that time we had gone a long way towards setting up farms of a convenient size. We had gone a very long way in

animal breeding, and some distance in the use of fertilizers and in inventing or introducing new types of machinery. In some directions, such as the control of certain pests, science had been a great help, but it would be incorrect to say that our agriculture was truly scientific or that the farmers themselves had developed the idea of thinking in terms of the procedures necessary to maintain soil fertility rather than in terms which had their basis in exploitation pure and simple.

Returning to British agriculture—with the end of the Napoleonic wars came also the end of a period of monetary inflation and economic collapse ensued. Prices of commodities fell and with them land values came down also. Agricultural practice went into a decline in which it remained for a quarter of a century.

The forces which started it again on the upward path were once more dual in nature. They were on the one hand economic, owing to a steady increase in the population with a corresponding demand for greater food supplies, and on the other, scientific. This was the period of soil amelioration, especially through drainage, but also by marling, liming, and clay burning. It was also a period of expansion in the use of all forms of manure from animal residues, such as bone derivatives, blood meal and guano, while chemical manures, such as superphosphates and the slags, were also manufactured and used for the first time. The use of farmyard manure, or "muck" as it is colloquially described, was raised in esteem till it became a veritable cult. Crops were diversified; the need for rotations was accepted on all sides. Farmers were thinking in terms of soil fertility; their ideas were often of the haziest kind, but the maintenance of this accepted principle became part of their creed, and they were prepared to carry on procedures which they considered would maintain it, even if such procedures were expensive and the results were not immediately obvious.

During this phase of what may be called primary intensification, scientific research began to be turned towards the assistance of agriculture. Naturally such research cannot proceed effectively beyond the stage to which pure science itself has developed. These were the days in which the foundations of modern chemistry were being laid. The application of the analytical outlook, dependent on those foundations, to the basic agricultural processes was greatly stimulated by Liebig and his school. The Rothamsted work started in 1843. The principal success achieved was in the direction of remedying the grosser forms of soil deficiency. In other directions pure science had not progressed far enough to render much valuable assistance. Numbers of analyses of crops and fodders were made and a certain amount of speculation arose as to what the accumulated data meant, but organic chemistry was not yet on its feet; even the structure of the sugars was not known: while the term "albuminoid substance", which covered a multitude

of types of nitrogenous organic compounds, reflects the general lack of specific knowledge without which critical experiments in animal and plant physiology could scarcely be expected. On the botanical side, the attitude towards varieties and hybridization and selection was very muddled. It would be quite incorrect to suggest that the effect of science was of major significance at this stage except in the correction of grosser forms of soil deficiencies.

The period 1835-1870 was one of marked improvement in procedures, and by the end of it the attitude of the farming community towards soil fertility had been brought to such a high pitch that no farm was ever let without restrictions being placed on the type of rotations to be practised, and on the right of the lessee to sell such items as hay or straw or roots which might be expected to remove from the area of the farm certain elements of fertility with them. These restrictions were indicative of high farming, they were possibly essential on soils which were subjected to intense leaching and which had been cultivated for a considerable period.

Economically the agricultural industries flourished up till the 'sixties', population was expanding steadily and was able to absorb both the increased production of British agriculture and also the importations from overseas which began to be considerable. In the 'seventies', however, the areas of arable country opened for wheat-growing in the Central Prairies of North America began to yield export surpluses which were larger than the British market could absorb, and the general price for wheat declined; Australian and Argentinian exports also added to the difficulty of over-supply, and the British farmers tried to turn their attention to other crops; but as is always the case under such circumstances, this merely resulted in bringing down their price in turn. Scientifically this price struggle was between British intensive agriculture with an emphasis on the care of soil fertility and using long cultivated soils, and other agricultural systems operated on soils which were still rich in virgin fertility or which were of such types as not to lead to early decline in fertility after a few years of cropping. Such soils are, of course, found in climatic zones where leaching is not a factor of importance. The new wheat areas were greatly assisted in the struggle by the intense development of cheap transport all over the world and also by the invention of the new types of machinery which we in Australia know so well. These new machines were specially suited to deal with places where land is cheap, labour dear, and yields per acre low.

The struggle was one of the causes of the great depression of the 'nineties' which affected not only Australia, but Argentine, U.S.A. and Europe. In it, British agriculture undoubtedly lost some of the ground it had gained during the forty years preceding the 'seventies'. The situation was partly relieved by the monetary inflation which followed the South

African war and the entry of large amounts of gold into circulation not only from South Africa, but also from Western Australia. The great war temporarily altered the whole scene, but its aftermath was doubly unfortunate for the countryside. In the first place the period of shortage of raw materials had led to an undue increase in the areas developed for farming in many countries, notably Canada, the Argentine and Australia, and secondly the subsequent deflationary period brought lower price levels for agricultural products. This overgrowth of farming ultimately ended in the Economic Revolution of 1929, with its train of currency instability, repudiation of international debts, internal moratoriums and the widespread distribution of the doctrine of national self-sufficiency.

Under the stress of this long continued economic pressure British agriculture has had a difficult fight. At times its efficiency has weakened somewhat, as during the period 1880 to 1900. Its capital structure has at times shown great variations—both in amount and in constitution. In the old days the farms were mostly rented, but with the break up of the squirearchy owned farms have become much more frequent. Its main hope of survival was for a long time based on prospective assistance from scientific research and education, and much has been achieved in this direction—this was now easily practicable, for the period at present under review has seen many notable advances in pure scientific knowledge which have been capable of utilization in agriculture. Of these, I would give first place to the development of satisfactory technique for planning and interpreting field experiments. Plant breeding and botanical systematics have made great strides. The advances in soil knowledge have not yet carried matters much further than the work of the preceding period.

The science of animal nutrition has been brought to a point where it is of very definite value to the farmer. These researches have all helped, but I doubt whether Britain has had any man or any organization to take the place of Arthur Young, 150 years earlier. Perhaps one may be permitted to wonder whether the ceaseless torrent of printed matter of all kinds which swirls past the farmers' eyes day by day has made it less easy for agricultural propagandists to achieve their objectives. In any case, it is extremely doubtful whether the British farmer could ever maintain his intensive standard by scientific aid alone in the face of the flood of produce which was ready to pour in on him from sources which were artificially primed through export bounties, "home consumption price" schemes or manipulated exchanges in the various countries of production. In order to avoid the results of this influx he has had recourse to political action in the tariff and the quota system.

I regret the length of this survey, but I will conclude it by summarizing the phases of the agricultural development of the British Isles as I see them.

Firstly, the purely exploitative 'open field husbandry' of Saxon times.

Secondly, the manorial system, a social device, agriculturally exploitative, but showing some glimmerings of the realization of the need for sound practice in its rotation of the crop land.

Thirdly, the developmental period of intensification only possible under a system of unit, as opposed to communal, management (1400-1814), with its forging of special tools for the special environments of the country, by trial and error methods carried out by many farmers.

Fourthly, (1835-1870), primary intensification during which permanent improvements, e.g., drainage, were developed on the land, and the importance of soil amelioration and the maintenance of fertility were fully appreciated.

Fifthly, the present phase of scientific investigation.

As I see them, these changes have always taken place only in response to economic pressures of one kind and another.

Agricultural Systems in Australia.

Turning now to Australian systems, traces of the same sequence can be observed, but inasmuch as our agriculture is yet young, it would be unreasonable to expect that its development should have proceeded to the same length. Further, the soil types of our continent show a very much wider range than those of Britain, and large tracts occur where leaching is relatively unimportant, so that, other things being equal, the surface layers may possibly be expected to contain greater reserves of minerals and plant foods. In addition, the precarious nature of the rainfall presents an added risk to the farmer, and the heavy expenditures required for intensification are not to be undertaken lightly. Finally, in many cases the price levels of agricultural produce in Australia are lower than in Britain, so intensification in methods of production cannot be carried as far.

With these preliminary observations I will now endeavour to examine some of the multifarious forms of production which the Australian agricultural and pastoral industries offer.

The wool industry opened in the simple exploitative fashion as was only natural in a country with vast areas available for grazing. It entered into its own particular version of the second phase when pastoral leases were widely developed in the early days. Actually, from the point of view of management this phase of development is in some ways comparable to the manorial farm system. Under it, more or less care is taken to avoid extreme over-grazing and to maintain the *status quo,* but even this is apparently lacking in some of the marginal country where exploitation with little thought of the morrow holds sway. The number of sheep carried in this purely exploitative way has declined since the 'nineties', while the number carried on farms and

stations in the developmental phase of intensification has correspondingly increased. Whether this decline in numbers of sheep carried on undeveloped stations is due to over-exploitation of the soils and the vegetation, I do not know, but I believe that that is the case. If I am correct, then the future will see a contraction of sheep-keeping on this second or purely exploitative type. At least in the outback country of low and unreliable rainfall, climatic irregularities render intensification too big a gamble to be considered as economically practicable. Sections of the wool industry have adopted more intensive methods, including pasture improvement and some attention to feeding, while treatment for pests and parasites is, of course, general. Only in those limited districts where the climate is such as to make the production of meat the really important part of the industry, is there anything approaching real intensification, and, as Hammond pointed out, scientific research has as yet scarcely been employed at all on many of the practical problems of the industry except on matters of pests and disease.

The wheat industry is particularly interesting. Its early development naturally occurred on the coastal areas where the soils are mostly partly podsolized except in the Adelaide plains region. These areas were farmed on a purely exploitative scheme, which was not successful for long except where manures were used in much the same way as in Europe. The opening of railways across the Ranges brought farmers into contact with the red, brown and grey, and Mallee soils which could in some cases be exploited without serious damage.

The invention of new machines and breeding of special varieties brought wheat farming into the developmental stage of intensification. This movement to areas of low harvesting costs destroyed the economic basis of wheat growing in the older areas near the coast, and, as already noticed, played its part in the threat to the intensified agriculture of Britain. In many of our wheat areas the soils proved unable to withstand the strain of continued exploitation. In some districts the cultivation declined, as the Goulburn Valley (Vic.). In others the rotation with fallow and the introduction of superphosphate warded off the evil day; but the present situation is to my mind far from satisfactory and science still has a big task ahead in devising systems of alternative crops to wheat which will maintain fertility and allow the land to be used more intensively than is the case under the fallow system. What these crops may be I do not know, but leguminous plants would obviously be advantageous, especially if Azotobacter is as infrequent as recent observations suggest.

The history of Australian dairying is particularly interesting. Each large city developed its dairy farms in the surrounding districts. Not one of the capital cities is located in a region where dairying may be carried on easily; consequently the systems which developed involved high costs during

the off-season of production. The discovery of refrigeration and the adoption of the separator and the Babcock test enabled the industry to reach export markets and become economically attractive during the 'eighties' and 'nineties', when many new districts were opened on a purely exploitative basis. The forests were felled, pastures planted and grazed without thought of soil depletion.

During the last ten years pasture improvement has made strides in many districts, and from this standpoint the industry has entered on the fourth phase. The other side of the industry which deals with the cows, largely remains in the second phase. On the great majority of dairy farms no records of the production of individual cows are kept. No careful study of the cows' response to supplementary feeding is made, no attempt is made to breed better animals; in fact, it is an exploitative industry. How far this is due to excessive land values and mortgages, how far it is possible to increase butterfat production by supplementary feeding and still make a profit, can only be discovered by careful observation and experiment. There is a clear case for scientific assistance to the industry, but it is necessary that the economic basis of the recommendations should be sound before they are put forward.

The cattle industry of the mountains and the outback stations of the North is in the first phase of development. The areas on better country are often managed on a somewhat intensive plan, but on the side of animal nutrition the methods are often of the roughest kind. The low prices often realized for the stock militate against forcing methods of feeding, nor does it seem likely that the most scientific systems would be likely to stand for long except where the conditions of the district are specially suitable. The ultimate competitor is the Argentine, where the natural pastures are apparently so well suited for this task that supplementary feeding is not often necessary. However, without scientific assistance little further development seems practicable.

The fruit industries offer numerous examples of local agricultural systems which have sprung up and then disappeared again under new pressures. Starting with viticulture: the wave of Phylloxera which spread through many vine-growing areas of Victoria in the 'nineties' eliminated the industry from Bendigo; again, vineyards producing select, dry wines were once cultivated at various places in the Yarra Valley and on the Bellarine peninsula; today few remain. The causes are alleged to be the diminishing demand for their produce, but it seems likely that inattention to the requirements of soil fertility may have been a contributory cause.

Years ago Melbourne was largely supplied with fruit from orchards grown within thirty miles of the city. Apples, pears, peaches and apricots were all produced in abundance. Most of the trees were grown on poor

soils, derived *in situ* from Silurian mudstone, and many of the plantations were on sloping land. There seems to be a tradition in Victoria that apple orchards must be grown on poor soils, presumably because the fruit raised from such trees keeps well on storage. However true this may be, soil poverty also means low yields and consequently the need for high price to repay the considerable costs of establishment. It follows that when orchards were established further away from Melbourne on deeper soils the competition became keen. Where the land was sloping and erosion carried the surface soil down into the creeks, the orchardists were confronted with the alternative of either attempting the Sisyphean task of carting it up the hill again or of trying to continue the cultivation of trees which were growing on subsoil. Both are hopeless propositions for an industry faced with a falling price level for part of its produce owing to oversupply of the export markets. Only those orchards on which continual care has been taken to retain the soil and maintain its fertility by growing cover crops and adding manures have managed to maintain their position. In many instances the slope has been the deciding factor. The pear growers have in many instances been far more careful and successful; recent advances in cool storage methods and better varieties have given them a wider market than formerly and they are still in a sound position.

The stone fruit men form an instructive study. Crops of stone fruit are often so prolific that only the early production pays. Prior to 1914 Melbourne peaches and apricots came from the local orchards; later the fruit from the irrigation areas near Shepparton began to arrive on the market earlier than the local produce, which became correspondingly unprofitable. In recent years the suburban growers have produced earlier varieties with which they are now able to compete once more on a profitable basis. Here then in these fruit districts we have a keen struggle in which only the most intense methods of operation are going to survive.

A somewhat similar story might be written of the citrus growers, whose gradual rise to efficiency has been a marked development of recent years. Nowadays all the more successful orange growers pay great attention to their soils, using large quantities of manures of various kinds, while the control of pests and bud selection are regarded as essential.

After all it is only natural that the orchardist should attain to higher degrees of intensification than other types of farmers. His capital outlay is considerable, and if he is a bad farmer the results of poor treatment are so disastrous that yields may be halved over many years and not in one season alone.

Market gardening is another rural industry in which a high degree of intensification has been reached. In Victoria success is not only dependent on this but is influenced to some extent by access to markets, a factor which

has militated against the success of Chinese operators. Nowadays, with our improved road transport we are witnessing an intense struggle between the suburban market gardeners and other growers, using irrigation water, in areas as far afield as Mildura, the earliness of the crops in the latter districts compensating for the long hauls necessary. In this struggle, intensification on poor and relatively unfavourable soils may ultimately be beaten by a somewhat less intense production assisted by improved transport and special features of the locality.

The consideration of other special crops, many of which require special conditions if they are to grow prolifically, at once reveals most interesting data. In most of our better agricultural regions we find instances of crops which have been established on a small scale in the past and which have rarely flourished and have disappeared altogether from many districts. These are usually cases where insufficient intensive work has been carried on by the farmers or their technical advisers to fit the new form of production into its particular environment.

Most of you will have read Mr. W. G. Wells's interesting account of the cotton industry published in our Journal in 1937. You will recall that there he expresses the view that cotton in many parts of Queensland is a rotation crop and not likely to give good yields when grown as a special line year after year even with alternating fallows. His suggestion that the vital factor for success consists in keeping the soil nitrogen from rising to too high a level seemed to me most thought provoking.

My knowledge of the cane sugar industry is largely based on its published data and statistics. No one who has followed these during the last ten years can doubt that the industry is reaching a higher level of efficiency through a more careful study of its problems. In the long run this will make it less dependent upon the somewhat grudgingly-given help of the Australian consumers, although paradoxically enough it may temporarily mean a higher quantity for export at an unremunerative price.

Rice is a special case in which success was achieved rapidly when once the suitable soils and the necessary quantities of water were available together. For that success, however, we are partly indebted to the studies made in California, whence our varieties were derived. It may be that rice growing is still too young an industry to assess its main problem, but this does not seem to be the case.

Flax is a somewhat difficult crop and in my opinion has never yet had enough scientific assistance to enable it to find its feet under our conditions. Recent experiments suggest that the new imported varieties give considerable promise, but I have little doubt that the crop will not be established permanently until its detailed requirements and the appropriate technique are

worked out to the fullest degree. It is a crop which is almost bound to be a failure in the hands of the pioneer.

Tobacco is a similar case. No one can say that it is as yet a successful crop in Australia. It is to my mind essentially a rotation crop and requires very clean cultivation and, if disease is to be controlled, the removal of debris after harvest. The harvesting wants continual care and calls for considerable judgment. That awkward triangle of forces, the quality of the leaf, the yield of leaf per acre, and the price schedule for various types, does not make the solution any easier in a commercially-minded world.

Our potato yields are desperately low and although it is easy to blame the climate and the season, such as 1937-38, yet I do not think that the climate can be expected to take the blame year after year. The truth is that neither the scientific study of the potato in Australia nor the intensification of the methods employed by most farmers growing the crop has been satisfactory up to the present time, although Tasmania seems to be now showing the way.

I have mentioned enough cases to illustrate my point, but in the majority of these crops Australian methods are, as yet, far from intensive. In many cases the exact soil factors necessary for satisfactory growth and production are either not yet known or not achieved in practice. In other cases there is some insect or fungus pest which is not effectively dealt with by the system of cultivation at present in vogue and which takes a heavy toll of the yield.

A third group of troubles comes from unsatisfactory varieties not well attuned to the periodicity of the climate in the districts in which the crop is grown. The correct adjustment and control of these factors is the real need in intensification, and in the achievement of this objective the agricultural scientists have their life work.

I have endeavoured to suggest that the Australian agricultural and pastoral industries have a great deal to learn in the way of intensification. I do not wish to burke the fact that here and there notable achievements stand out. For instance, the wool industry has learnt the technique of producing a really high grade product. It has not been very scientific in its methods, and it has often achieved its objectives with little or no regard for the nutrition of the sheep and with a complete disregard of what is happening to the grazing plants. It has had the finest tract of country in the world for sheep grazing, and it has exploited it very well. In the Wimmera (Vic.), the Adelaide plains and Lower North of South Australia, and a few other districts, a system of intense wheat growing has been developed which is extremely efficient from the point of view of production. Farmers aided by scientists have devised methods under which the inherent fertility and special qualities of these soils are turned to great advantage. I

find it difficult to think, however, that the wheat-fallow system can be accepted as a final stable type of agriculture. It may be that the soils are sufficiently deep to enable this system to last our lifetime, but I am convinced that sooner or later yields will begin to decline under this method of management as they have elsewhere.

It will be observed that my definition of intensification of agriculture implies the adoption of agricultural systems which will retain soil fertility; and this in many instances necessarily implies diversification of forms of production beyond the few lines at present grown on such a large number of our farms. In my opinion the specialization of farming for one form of production is usually a mistake in the long run, particularly the specialization of cropping without the utilization of the grazing animal and, even more particularly, the specialization of such cropping to one particular crop. I believe that agricultural and land policies should, whenever practicable, be directed against such systems. This implies some consideration of systems of land tenure. It is clear that large grazing estates on soils suitable for agriculture and in good climatic regions are not in the best interests of good agricultural policies. At the other end of the scale, share-farming is seldom really desirable unless the conditions are carefully considered when drawing up the agreement. Further, the one-man farm is usually a mistake. This leads me to the question on which I cannot here enlarge, but which I am convinced is a major factor in our agricultural progress, namely the relationship of intelligent paid labour to living conditions on farms. All these matters are important and require attention if the development of our future agriculture is to follow satisfactory lines. In addition, a vast amount of scientific research and investigation coupled with careful extension work is also essential.

There are, of course, those who think that systems of agriculture which are either haphazard or exploitative do not matter. I would suggest the following reasons why this is not the case:

In the first place, the soil is unnecessarily depleted of its inherent fertility, and in many cases it is doubtful whether it can again be raised in this respect without prolonged treatment.

Weeds and pests seem to flourish in such cases and badly run farms may act as foci for their spread to adjacent land.

Then, undue reliance on the returns of a single crop or product is economically unsatisfactory and leads to recurring periods of financial disaster. The growing of subsidiary crops has the additional advantage of spreading the work over the year.

Further, unintensively produced crops tend to have low yields and correspondingly high costs per unit produced. In Australia, the consequent tendency is to demand and obtain a tariff or a bounty. In both cases this

involves public expense which, either through the food items in the basic wage computation or in other ways, ultimately reacts on the whole cost structure of the nation. Such criticism does not necessarily apply to subsidies given to industries to tide them over relatively short periods when world prices are unduly low, but such assistance to an industry should have some regard for the general level of price of the commodity in the world.

Moreover, high costs for agricultural produce damage other branches of agriculture severely. For instance, if maize is badly grown and costs are higher than they need be (please notice that I said *if*, for I do not know whether maize growing is efficient or not), then farmers who would use cheaper maize as a supplementary food for stock cannot afford to do so, and they in their turn are prevented from attaining proficiency. In this way one badly organized rural industry may affect may others.

Again, the psychological effects of intensive agriculture are very marked. I suppose every one of us must have been impressed by the difference in outlook towards life between farmers who have achieved success through efficient work and those whose story has been one of partial success and numerous failures through indifferent or poor management. In his heart the farmer knows whether he is doing a good job or not, and respects himself accordingly. I will not elaborate the point, but I believe it to be one of major significance.

Then, the farmer who tries his hand at some new form of crop production or some variation in practice and fails, tends to lose faith and refuses to adopt any new ideas whatever. Careless advice or advice based on insufficient knowledge may thus do much harm. Similarly, misguided attempts on the part of quasi-scientists or commercial organizations of the go-getting type inspired by questionable motives have often led to foolish agricultural development, whole groups of farmers losing their money and faith as a result.

Finally, the farmer complains that the tariff has raised his costs, and in the prime cost of developing land this is certainly correct. On developed land, other than in marginal districts, it may well be urged that the major effect is to restrain the advance of land values. However that may be, it is clear that nowadays the country is obtaining nearly as much assistance from the urban population in the form of bounties, home consumption prices, special taxes and so forth, as the urban populations are obtaining for their sheltered manufacturers. Sooner or later this policy may lead to a condition of unwholesome strain in the relations between these two constituent groups of the national life. This would be definitely disadvantageous and the more intensive the culture the less call there should be for assistance.

It may be remarked that I have not allowed for the law of diminishing returns. I know there are probably cases in which it may apply. For

instance, I admit I do not *know* what is the economic basis of supplementary feeding of dairy cows for butterfat production, but I feel sure that the number of cases in which the operation of this law prevents economical intensification is relatively slight.

Some will remark that there will be difficulty in finding markets for the extra production consequent on a steady increase in efficiency. A few seconds' thought may overcome such fears. The results of such a movement would not be immediate, and the population in the meantime is increasing and its effect is more marked than one would generally suppose.

The rate of natural increase is at present 25,000 per annum, which means that without any allowance for migration the annual increase in the number of mouths to be fed in Australia is equivalent to 22,500 "adult male units" on the Burnet and Aykroyd scale of nutritive units. If the national dietary remains as at present, this will involve the intensification of agriculture by 50 per cent. on roughly 157,000 acres annually. This is rather a startling figure, and it is interesting to note that the industries most affected will be those requiring high-grade production on good land of which we have not an unlimited quantity, namely dairying, potato, fruit and vegetable growing.

The problems of intensification are really the problems of the agricultural scientist and his attendant propaganda department. In so far as the members of this Institute manage to unravel the tangled skein of factors limiting the efficiency of each type of crop, they will enable agriculture to progress in Australia. In so far as they are able to estimate the effects of the various systems of cropping on the soil, they will do something towards averting the steady deterioration which I believe to be taking place in many districts.

Soil Conservation and Permanent Agriculture*

By

Sir E. John Russell, O.B.E., D.Sc., F.R.S.,
Director of the Rothamsted Experimental Station, and of the Imperial Bureau of Soil Science.

The problem we are met to discuss today is widespread. Already there has grown up a considerable literature about it, and a great deal of experimental work has been done. I need only refer to two recent Australian publications: the Report on Soil Erosion issued in South Australia, and a circular published a few weeks ago by the Bank of New South Wales—both very illuminating documents.

Although the interest in this subject is modern, the problem itself is very old—as old, indeed, as our civilization. The land round the Mediterranean was in prehistoric times mainly covered with forest. As mankind spread over this land, the forests were cleared, and on the fertile soil good crops of grain and other foods were grown. Then populations grew, and commerce arose, requiring the felling of the trees for timber, for fuel, etc.—and nothing was put in their place. Grazing animals increased also, consuming everything that started into growth. The result was that the soil lost its vegetation and before long it ceased to be soil. In Italy much of it, especially on the pleiocene clays, got washed away; and in North Africa, land which had been green fields reverted to desert sand. It sounds a modern story: actually it is 2,000 years old.

It so happened, however, that to the north and the west of Europe there was abundance of virgin forest which could be cleared and the land tilled; in this direction agriculturists migrated. Their methods were probably not very different from those of the Mediterranean, but the results were completely different. There was no erosion to speak of, and the agriculture remained permanent. The system, as practised in England, consisted of two corn crops followed by a year's fallow—not the cultivated fallow of today, but a natural growth of weeds which could be grazed by the cattle, and dunged, and then ploughed up for winter corn. In England and other parts of north-west Europe, the system survived for more than 1,000 years, and there seems no reason to suppose it would ever have given out. It was, of course, helped by the Feudal System, probably the most conservative political organization we have ever had. The system was improved in England in

* Opening address at discussion on "Soil Erosion" at the Canberra meeting of the Australian and New Zealand Association for the Advancement of Science, January 13, 1939.

the 18th Century by being converted into the four-course rotation—roots, barley, clover, wheat—and this too was permanent. There was no soil erosion such as had occurred in the Mediterranean.

The reason for this striking difference is now known: it is related to the effect of the growing plant on the soil. The permanence of the soil in north-west Europe is due to the fact that a vegetation cover quickly establishes itself, while in the Mediterranean region it does not. In England, the vegetation cover, especially the clover introduced in the 4-course rotation, kept the soil permanent. A further factor was that the trees were never entirely cleared; in spite of over 2,000 years of agriculture, England is still very well wooded.

The modern problems of soil erosion date from the second half of the 19th Century. There was a great migration from north-west Europe to North America, and much virgin land was broken up for agriculture. This in itself need not have seriously affected the soil, but a special type of farming was developed which proved to be very harmful. The rapid industrial developments in England and on the Continent caused a great increase in the population of the towns and a larger increase in the demand for food, especially bread. Now, wheat production is the easiest of all kinds of farming for the migrant; it needs the minimum of capital and skill, and the risks of loss are much less than in many other branches. There was always a demand for wheat, though prices might be low. Wheat became very popular—great areas were cleared in order to sow more wheat, trees and bushes were cut down and the native grasses removed. The building of the railways across the United States and across Canada, and the establishment of the very efficient transport arrangements, brought large areas of prairie land into cultivation. The climate differs from that of north-west Europe. The winters are cold and dry, the summer apt to be very hot and dry; the rainfall tends to be seasonable and, when it comes, is sometimes torrential. Sometimes in the summer the winds are very high.

In these conditions the varieties of wheat grown in north-west Europe did not usually do well. New varieties were sought in central Europe, Russia and northern India, where the conditions were more comparable. The difficulty about the long dry period was overcome by fallowing. During one year's fallow, sufficient moisture was stored in the soil to help the next crop very considerably, and by a system of one year's fallow followed by two years' wheat, it was usually possible to obtain yields which were sufficient to furnish some sort of a living for the farmers. The idea gradually arose that the moisture would be better preserved if the fallow were well cultivated, and disc implements were used to produce a fine surface mulch. In general, the straw could not conveniently be handled and so the grain was merely stripped and the stubbles burnt.

Now most of this was in accordance with the accepted scientific teaching of the day. The system was certainly recognized as exhausting of humus, which was regarded primarily as a source of nitrogen for the crop, and there was some fear that the plant food in the soil would become exhausted, but so long as this contingency was not in sight, the system was expected to go on. It closely resembled the old three-course system in north-west Europe that had lasted about 1,000 years; the yields were often of the same order, and as it had lasted so long in Europe, there seemed no reason why it should not continue in America.

Then, however, came a rude awakening. The soils on the western wheat farms started to fall to a fine dust that easily blew away in the high winds, and gradully this soil drifting became more serious till finally it attained the dimensions now seen in the Southern Great Plains of the central States and in Saskatchewan. You have it here also in the Mallee country. Spectacular losses have occurred in Victoria and South Australia. Great expense has been incurred in keeping roads and railways and water channels clear, but there has been a far greater loss due to deterioration of the land. These losses have been incurred for the same reason—the replacement of the natural vegetation cover by the less efficient wheat-fallow cover. Elsewhere, the rain gradually washed away the surface soil by the imperceptible process of sheet erosion, while in places the washing away of the soil led to dramatic destruction, and great gullies were formed, making the land useless for any purpose whatever. Gully erosion is less here than in the Central States, yet it is quite serious in parts of South Queensland, New South Wales and Victoria on a belt running from the Darling Downs on the inner side of the Great Dividing Range into Victoria. The destruction of the soil has come, not from any exhaustion of plant food, as the 19th Century agriculturists had feared, but from the destruction of its texture and from the actual mechanical removal of the soil. The situation was exactly the same as had appeared in the Mediterranean region 2,000 years earlier, but it was made vastly worse by the much greater pace of modern activities due to the far greater efficiency of our cultivating implements. The cause, however, has been the same—the destruction of the natural vegetation cover which had formed the soil and held it together, and its replacement by a vegetation scheme which was far less effective as a soil maker and soil conserver.

Another kind of soil destruction was started about the same time. For certain reasons which we need not discuss, a number of farmers in Cape Colony decided to migrate into the grasslands further north. They were pastoralists, and the grass was tempting: they went, and began grazing. In places, the result was entirely successful, but cattle diseases periodically broke out and caused serious losses. Then a good veterinary service was set up, the diseases brought under control, and the cattle population started

increasing. The vegetation cover was not very dense; it was grazed hard. The climate was, on the whole, dry, with a long dry season, then rain which might be torrential. Usually on the pastures the water supply for the animals was restricted to a few places. The animals frequently, in accordance with their custom, walked in single file, so compacting the soil and making a long small depression. When torrential rain came, it started running off the land along these depressions, carrying the soil with it, gathering force as it went, and finally scooping out great gullies called dongas. Matters were made worse by the burning of the grass, which was done periodically to destroy the ticks and also to ensure a growth of young good grass for the animals. Agriculturists disliked this practice, but could suggest nothing better. Apart from this, there had been no infringement of the laws of good husbandry as understood in north-west Europe. Compacting of the soil by animals as they walk along it never causes trouble in England, and hard grazing is recognized good practice; indeed, a Romney Marsh grazier once told me that on a well-managed pasture you should be able to throw a two-shilling piece as far as you can and still find it. But the results have been disastrous, especially on the clay soils. Overgrazing is one of the most serious causes of erosion in Australia.

A third type of soil destruction took place in Ceylon. Here there is no dry season, but a high rainfall which is sometimes torrential. Vegetation grows well and a cover is quickly established. In the hill regions, tea and coffee plantations were started; the trees and bushes were cut down, the tea or coffee plants were planted, and, according to good western European practice, the plantations were kept nicely hoed and free from weeds. Then erosion began: the heavy rain washed the soil away and serious destruction set in. Clean weeding is now recognized as bad, and selective weeding is being tried, or else the planting of some crop that will give cover, but not compete too seriously for the soil nitrogen. In Malaya also, this "clean culture" is being given up in favour of a "forestry system", where much undergrowth is left. Deforestation is a very potent cause of soil erosion, and it has operated in many places, because the 19th Century migrants seem to have had a complex against trees and regarded them as pests to be destroyed rather than as allies to be preserved.

Another source of damage almost as harmful, particularly in Cyprus, Palestine and Africa, is the grazing of the forest by domestic animals. So long as animal diseases and pests, tsetse fly, etc., and wild animals abounded, the animal population did not usually become numerous enough to do much damage, and tribes were often given rights of grazing which were at the time unobjectionable. But with the development of an efficient veterinary service, the animal population has increased so much that the forests are badly damaged, and the growth of human population necessitates the clearing of more forest for the planting of food crops.

In none of these cases had there been any break from the classical rules of good practice. The agriculturist could therefore hardly be blamed. Indeed, it could not be said that the trouble originated with him at all: it arose in North America through the development of transport and certain movements in the wheat market; in South Africa through certain political and economic developments which led to the northward trek; and in Ceylon through a rising standard of life in England. These had no immediate concern with the soil, but the new vegetation relationships to which they led were unstable and so destruction of the soil ensued. Soil erosion is not merely a soil question—it involves the whole problem of soil utilization, indeed of country life. Its very breadth makes it difficult for a democracy to control.

Before proceeding to the discussion of remedies, I must discuss two other types of soil change, sometimes also called soil erosion, though they are so different that they should be kept distinct. Nevertheless, they are intimately bound up with the subject and must be included here.

I have spoken of the agriculture of England and of north-west Europe as permanent so far as the soil is concerned. Twice during the 19th Century, however, fears were entertained that the land might become exhausted through the using up of plant food. The first was in 1840, when Liebig, in his very vigorous and outspoken "Letters on Chemistry", argued that potash, lime, phosphate and other mineral substances required by the plant were removed by the crop, and when the supplies were exhausted the soil would become sterile. He indicated the remedy, however; it was only necessary to add these mineral substances as fertilizers. Lawes and Gilbert at Rothamsted showed how this could be done; they proved also the need for nitrogenous fertilizers. The problem seemed solved till Crookes, in 1896, in his famous British Association address, showed that the supplies of nitrogen fertilizer in sight were no longer adequate for the growing requirements, and world starvation might ensue if no new sources could be found; he expected it somewhere between 1935 and 1940. He also, however, indicated the remedy, and showed that the gaseous nitrogen of the atmosphere could be made to combine with oxygen and so to provide nitrates: the potential supply was thus inexhaustible. Fears that plant food might become exhausted are therefore banished for ever, or at least until all the phosphate deposits are used up, which will not be for a very long time. Even without fertilizers, however, exhaustion of the plant food in the soil proceeds only very slowly. At Rothamsted, several plots have been without manure for many years—one since 1839. It has been cropped with wheat every year since 1843, yet in 1938 it yielded 24·6 bushels per acre. The yield has never been higher than this, and obviously it will be a long time before this land is exhausted; yet even at the beginning it could not have been classed

as fertile soil. For many years the yields were lower, but we have always had difficulty in keeping down weeds and arranging proper cultivations; recently we have been more successful.

The effect of a fallow is very remarkable; part of this unmanured plot was fallowed in 1937 and this gave 39 bushels of wheat per acre in 1938—although it has been without manure for 100 years.

Of course, one must not jump to the conclusion that fertilizers are unnecessary for wheat. The best manured plot gave much higher results.

In any case, a yield of 26 bushels of wheat represents only about 25 cwt. per acre of dry matter in the total produce, and while this is in many regions satisfactory for wheat, it is not sufficient for other crops. On the continuously unmanured plots, several of the common crops, such as wheat, barley, potatoes and mangolds give somewhere about the same yields of dry matter in total produce per acre, but for potatoes and mangolds these yields are entirely uneconomic in all conditions. When fertilizers are added, all these yields go up; the wheat and barley can be doubled, the potato yields are pushed up four times, and the mangold yields about eight times. One could never make a soil sterile by cropping it without manure, but one could never make a living by the process.

There are, of course, soils that begin by being almost sterile, such as some of those that are very deficient in phosphate and become productive only when phosphatic fertilizer is added; and there are soils lacking in some of the minor elements, such as boron, copper, or manganese, on which cultivated plants develop special diseases until the lacking substances are added. But these are natural defects not caused by human agency.

There has been much discussion as to how far it is possible to destroy soil fertility in moist temperate climates simply by allowing the organic matter in the soil to become depleted. Can fertility be maintained simply by the use of fertilizers, without even adding farmyard or other organic manures? The Rothamsted experiments with wheat and barley show that the rate of deterioration of yield is not appreciably greater on the plots liberally supplied with fertilizer, but without organic manure since 1839, than on the plot which has received farmyard manure since 1843, but the dressings of fertilizer have to be larger than in ordinary practice. On the other hand, it seems impossible to obtain large yields of potatoes or of sugar beet without farmyard manure.

It seems to be impossible, however, to exhaust the organic matter of the soil; on none of the Rothamsted plots is there less than about 0·09 per cent. of nitrogen or 1 per cent. of carbon in the surface soil. Various recuperative processes appear to prevent any further falls.

So far as is known, the only exhaustion that can become serious in cool, humid regions is the exhaustion of lime from the soil. This is a very real

danger. It is not serious in the Mediterranean regions, and the Roman writers on agriculture have nothing to say about it. But it has always been a source of trouble in north-west Europe, and before the dawn of history the Belgic tribes had learnt the necessity of putting chalk or marl on to the land. Pliny describes how they did it, and right up to the time of the War, the farmers in the south-east of England, where the Belgic tribes had formerly lived, still followed the same practice in much the same way.

The older chemists considered that the lime was needed to neutralize acidity, but its function is now known to be much more complex. The clay constituent of soil is one of great importance for determining its fertility; it is a mixture of various minerals in each of which the basis is a complex combination of silica and alumina; the architecture of the molecule is gradually being revealed by X-ray analysis. In kaolinite, one of the most important of these constituents, the silicon-oxygen tetrahedra, are linked by their corners into hexagonal groupings, forming an endless sheet; these alternate with aluminium hydroxyl groupings, each aluminium atom being linked with six hydroxyl groups in a hexagonal arrangement. The ties between the two sheets are effected by replacing one hydroxyl for each aluminium atom by a free oxygen link from the silicon-oxygen layer. In another important clay constituent these layers do not alternate indefinitely; they are arranged in sandwiches, each aluminium-hydroxyl layer being between two silicon-oxygen layers. Between the sandwiches are spaces into which water molecules can penetrate, so causing a swelling of the clay. These complex groupings can associate themselves with cations which are easily replaceable by other cations, even large ones like the complex organo-metallic cations; hence they are supposed to reside on the surface of the group.

In a normal fertile soil, the cations are chiefly calcium; it is to this calcium clay that all our agricultural methods and crop varieties are adapted.

In regions of high rainfall and low temperature, where the conditions favour the leaching of rain water through the soil, as, for instance, in the coniferous forests so typical of these conditions, the organic matter decomposing at the surface of the soil forms acids which, in washing through the soil, remove some of the calcium from the clay, replacing it by hydrogen forming an acid hydrogen clay. As the replacement continues, some of the clay minerals become unstable, they lose silica, alumina, iron and other oxides, which are carried downwards by solution or suspension and deposited lower down in the soil. Thus the soil tends to arrange itself in layers. The top layer is acid organic matter; below is the leached layer devoid of plant food and very infertile; below that again the layer in which the various substances removed from above are deposited. The process has been much studied in Russia and commonly receives its Russian name, podsolization.

This arrangement in layers, however, is a most infertile one for a soil, but, unlike erosion, it cannot be attributed to human agency.

There are thus two definite but very different types of soil destruction. One is this leaching process, that goes on in conditions where, as in northern Europe and certain coastal regions in Australia and New Zealand, water can soak through the soil, carrying with it the calcium cations, which are then replaced by hydrogen, causing ultimately the breakdown of the clay mineral. The other is the destruction that takes place in the warmer, drier regions of the world, where vegetation only slowly establishes itself, and where the destruction is due to the breakdown of the soil crumbs and their removal either by wind or water. Although as a breakdown process this is much less drastic than the other, its effects are much more serious because here the soil is lost altogether, whereas in the podsolization process the constituents are not usually very widely separated and they can in general be put together again.

In between these two sets of conditions are the soils where the leaching is insufficient to cause serious podsolization, and where the rainfall is high enough and the temperature low enough to prevent serious erosion. It was on these lands that the agriculture and the civilization of north-west Europe developed over the course of the last 2,000 years, and it was not till men had to migrate from the conditions of soil stability to those of soil instability that the problem became serious.

We must now turn to the question of remedies. Although podsolization represents a much more fundamental breakdown of the soil than erosion, it is in practice easier to remedy, and much is being done now in Denmark and elsewhere: the problem is important in some of the coastal parts of Australia. Lime is added to neutralize the acidity of the humus and to reconvert the hydrogen clay into calcium clay, and the land is ploughed or cultivated deeply to break the pan and, if practicable, to bring the lower enriched layers up to the surface. The necessary lime and manure must be added to provide the proper conditions for growth. Prevention, of course, is the better plan, and this consists in giving regular dressings of lime so as to maintain the preponderance of calcium cations in the clay and the humus, thereby preventing the break-up of the clay minerals. Periodical deep ploughing is also necessary to bring to the surface substances that have started to wash down.

Here again is a marked contrast with the hotter, drier conditions where neither lime nor deep ploughing is needed. Indeed, both practices could frequently be harmful. And yet, for podsolization as for erosion, the fundamental factor is the vegetation cover, and the trouble is greatly reduced by growing a dense crop like grass which reduces the percolation of water and so diminishes the leaching.

The remedies for soil erosion are much more difficult in practice, though they are simple enough in principle. First, the movement of the soil must be stopped, the gullies and dunes must, if possible, be levelled, and a vegetation cover must be established—all frequently very difficult tasks. Soil erosion has been faced more courageously in the United States than anywhere else; there has been no concealment of the facts, but a bold policy first of research and and then of action has been adopted.

The stopping of soil drift due to wind is done in two ways: setting up wind breaks, and by planting some vegetation that will fix the sand or soil and stop its movement. A gigantic scheme for planting shelter belts on about a million acres of farm land within a zone, 100 miles wide and stretching from Canada into Texas, has been begun in the United States. The planting of blowing sands with various grasses is now a well recognized device with various ingenious modifications; e.g., Whitfield suggests the planting of only the lower parts of the dunes, leaving the upper parts loose and exposed, so that they might be blown into the hollows, thus making the wind do the levelling. In the Plain of Sharon in Palestine, the sand dunes round Caesarea, which before the advent of the British had done much harm, are being fixed and will be afforested.

The stopping of water erosion is done by setting up obstacles to the running away of the water. Sir Frederick McMaster, in New South Wales, keeps a good vegetation cover, and at regular intervals ploughs two furrows along a contour. Elsewhere obstacles are set up which vary from a low bank of earth to a solidly constructed dam. The need is especially great on clay soils where water does not easily soak in, and where therefore the "run-off" tends to be high. The old method of doing this was by a system of terracing such as the very early or prehistoric lychets on the chalk downs of England, or the terraces built up with stone walls in the Mediterranean countries, and in parts of India and Africa. On steeply sloping land this is very effective, but where the slope is less, an easier method can be used—contour ploughing and contour draining with the setting up of wide, shallow banks, the so-called Mangum terraces named after their inventor, the United States farmer Priestley Mangum, of Wake Forest, N.C. The Nichols terraces are sometimes better. Another method, much used in India, is to set up bunds or banks across the depression along which the erosion will go. This question of run-off is extremely important, and where it can be dealt with it should be, even though the cost far outweighs the value of the land involved, because the eroded places become centres of activity from which further erosion proceeds, sometimes drastically. This method is practised with great success in Japan, where much of the land is very steep and therefore specially liable to serious erosion. Great skill is shown in setting up check dams of sufficient height to allow the soil to remain long enough to cover

itself with vegetation. The cost of the work is high, but it is not as great as the damage that would otherwise be done. Next to the Americans, the Japanese have probably dealt more courageously with soil erosion than anyone else.

Prevention is better than cure, and the run-off can frequently be reduced by afforesting the higher ground. The close association of the Forestry Departments in soil erosion work is essential. Good examples of the value of this collaboration are seen in India, where the problem is now well in hand in those forests which are in full control of the Forest Service. Felling of the trees is regulated, as also is grazing, and both have improved in consequence. The natives, who before were in danger of losing their grazing, now have more than ever. In Cyprus, which is fairly densely populated, a modification is made by planting fruit trees instead of forest trees, and developing horticulture which necessitates contour working and draining.

It is, of course, essential to secure a vegetation cover. Some natural vegetation may itself spring up and prove sufficient to remake a surface soil. Studies of regeneration of the vegetation cover are urgently needed, e.g., the re-establishment of Mitchell grass after droughts. The ecological approach to the subject has been well worked out by Shantz and by Clements in the United States. In some cases afforestation, in other cases horticulture, may be deemed the most practicable method. But for large areas the best plan is the working out of a system of permanent agriculture, one in which the cropping scheme suits the soil so well that it will remain fixed at at least its present level of productiveness. This may be either pastoral or arable, depending on the conditions. If it is to be pastoral, there will probably be need to find some good grasses and clovers. Two methods may be followed: (1) careful selection of the most promising strains of the native grasses, and (2) new introductions; and here the African highlands and the Mediterranean regions are a valuable source of hopeful varieties. This search for new crops and new varieties is one of the most important parts of soil erosion control. The permanence of the pastures depends on their management, which also necessitates a good deal of investigation.

Rotational grazing and, above all, avoidance of over-stocking are essential conditions. Pasture improvement is closely linked up with avoidance of soil erosion. Where arable cultivation is to be adopted, the most important factor is the type of cultivation—monoculture, i.e., continuous cropping with one crop, is much worse than rotational cropping.

At the Missouri station, M. F. Miller has shown that maize, cotton and tobacco are the worst crops in their relation to erosion, especially when, as usually happens, they are grown continuously. Certain rotations, especially those including grass sods or leguminous crops, are very considerably better.

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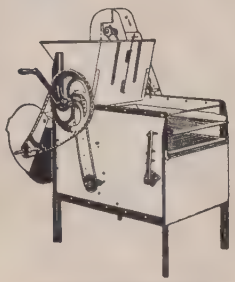

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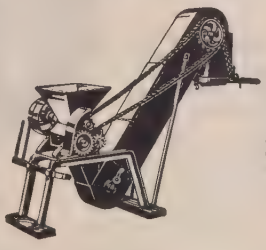

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This protecting effect of clover and grasses is due partly to the interception of rain by the canopy of vegetation, partly also to some effect of the plant roots in building up soil grains.

Particular care is necessary to preserve the vegetation cover once it is re-established. Alternate strips of ploughed and unploughed land set at right angles to the direction of the prevailing wind have done something in western Canada to reduce wind erosion, especially when combined with the unploughed fallowing, in which the summer cultivation is done with surface culturing implements only, and the weeds, or "trash" as they are called, are not buried, but left lying on the surface to give mechanical protection to the soil.

The problem of preventing soil erosion resolves itself into the working out of some cropping system that will give at least as good protection as the natural cover, but at the same time will furnish usable or saleable materials. It is very difficult to do this where a single crop dominates the agriculture, because, with the exception of grass and forest, no single crop confers the necessary stability, and continuous wheat-growing is likely sooner or later to kill itself by sheer destruction of the soil. The best hope is for mixed farming, where both livestock and grain are produced, and where grasses and clovers necessarily play an important part. But this, of course, means livestock and higher production, and in a world which prefers guns to butter the prospects for more intensive methods are not indefinitely good. Probably the best type of settlement now is not the wheat or dairy settlement catering for a world market, but a community settlement where a self-contained group of people is settled, each capable of rendering some service to the community and receiving in return his requirements for living. Here a general type of agriculture would be needed, and, so far as one can see, the soil could be indefinitely conserved and its fertility increased as the result of the cultivation. A community of this sort, not producing primarily for the world market, would never be a menace to other producers; it would primarily produce for itself, exporting only its surpluses to pay for things which it needed from the outside world. There were settlements of this kind in the early days of colonization, and I believe this more general type of settlement might succeed.

There is, however, no shirking the fact that soil which has taken long periods of years to create is now being rapidly destroyed by this generation. This generation has used more minerals, more oil, destroyed more forest and more soil than all the generations that preceded it, and all to very little purpose. But confining ourselves to the soil, which is a big enough problem, a particularly heavy responsibility lies on the peoples of the British Empire because we occupy so large a part of the earth's surface.

The first step in my view is to make a survey of the soil resources of the Empire, each of the great Dominions, of course, making its own survey, but on an agreed plan, so that the results of the different parts would be comparable and so that they could serve as a basis to show later on whether the soil fertility is increasing or decreasing. This is not the place to discuss the details, but the plan would include the present utilization of the soil and would bring in any available records to show whether the land is better or worse than it was. This would show also what degree of success had been attained by the preventive or curative measures taken against soil losses, and so would give valuable guidance to the staffs dealing with soil erosion. It would also indicate the way to more permanent systems of agriculture.

One final word. The forces bringing about soil erosion are no respecters of state boundaries or of departmental allocations of duties. The unit involved may be a whole river system or even more. The worst erosions, as we have seen, resulted from agricultural practices that had proved quite sound in England, and they came about through political or economic changes that had nothing whatever to do with the soil. But erosion may also be caused by faulty planning of roads and railways. Once soil erosion begins, so many departments are apt to be involved as to make effective coordination very difficult—yet lack of coordination has often been one of the most serious causes of erosion. The remedial measures may conflict badly with private rights, or State or tribal rights, as guaranteed by treaty, and very awkward administration questions may arise. It is here that the American and particularly the Italian organizations have advantages, for one authority is set up empowered to bring together all parties concerned. The Soil Conservation Service of the United States covers a very wide field of activities, and has absorbed the various local and regional bodies formerly concerned with soil erosion. One of its most efficient erosion authorities, the Tennessee Valley Authority, has found it necessary to take over the supply of water for the Tennessee River to ensure always a 9-foot waterway, the generation of electric power, production of cheap fertilizers, reorganization of agriculture, redistribution of population, afforestation, soil control and other duties.

In Italy, land reclamation is "bonifica integrale" (the adjective "integrale" means "all embracing" or "treated as a completed whole"); it includes the whole of the works necessary: the technical processes, land settlement, road-making, the building of new towns; these all come in as part of one scheme treated by one organizing or administrative body. Only on this wide basis is there any chance of remedying soil erosion or of preventing it.

Much as we dislike it, we may be forced to greater control. It is certain that once erosion begins, no effort should be spared to stop it.

William J. Farrer*

By

Geo. L. Sutton,
Western Australia.

As a colleague, very closely associated with the late William Farrer during the later years of his life, I am grateful for the opportunity afforded me by the Honourable Minister of conveying to you some impression of the man, rather than of his work.

Though a native born Briton, Farrer was of the tall spare Australian type. From a bearded face his grey-blue eyes looked out into the world through his spectacles with a kindly expression. It would be difficult to find a more modest, unassuming or unselfish man than Farrer. To know him was to respect and admire him. Until he knew you he was reserved, but with this reserve overcome was to find a cultured gentleman, just and honourable in the extreme, broadminded with wide vision, amiable and hospitable. He was not an impressive speaker, but was a forcible writer, and mentally—not physically—a great warrior. As a master of English he dearly loved a foeman worthy of his pen.

As an instance of his broad vision, it may be pointed out that 70 years ago the great importance of pasture research, now so recently recognized, was realized by Farrer. At one period before he settled down to his life work in connection with the improvement of wheats, he found himself at the crossroads of Grass Improvement or Wheat Improvement. The uncertainty of the wheat harvests, due to their decimation by red rust, led him to take the road to Wheat Improvement. His master mind chose the most urgent problem.

The little paddock of about three acres on our right, with its thin and unkindly soil, was his field laboratory in which he grew his wheats—his successes and his failures. Because of the exploratory character of the work there were many failures, but failures neither daunted nor discouraged him. To him a failure was as encouraging as a success, provided a valuable conclusion could be wrenched from it.

Farrer commenced to work in a new and unchartered field; there were many opinions regarding the solution of its problems, but little tradition and fewer facts to guide him. Even the tools of his new trade were not obtainable, and he had to fashion his first forceps for making crosses out of a hairpin.

As a scientist, Farrer wanted facts about the new problems, for, as he said, "you cannot argue about a fact". Though facts were so greedily sought

* Address delivered at the unveiling of the William J. Farrer Memorial, Lambrigg, in the Tharwa district, N.S.W., on January 16, 1939.

after, opinions were also and always invited, but the respective values of the two were never confused. Opinions were always welcomed, and though they were often at variance with his own, they were given that amount of generous and sympathetic consideration to which they were entitled because of the status of those presenting them.

Though naturally of a kindly disposition, his mental make-up made him impatient of mere aggressive assertion, but no man was more ready to listen to the views of others and, if necessary, to alter his opinions and methods accordingly. A typical instance will illustrate this. On one occasion he came to visit me at Cowra. When I met him I said: "You look particularly pleased." "I am", he replied; "Bob Hurst [his working assistant at the Wagga Experiment Farm] told me this morning I was wrong, and I have just discovered he was right."

Facts, though sometimes upsetting preconceived ideas, were always welcomed as aids to remove barriers from the path of progress.

Devoted Scientist.

As a careful and hard working scientist, Farrer had no superior. The magnitude and detailed character of his work are abundant evidence of this. Carlyle has said that: "Genius is an immense capacity for taking trouble." If this be true, Farrer was a genius of the very highest order, as those familiar with his methods will readily admit. The care and attention to minute details were remarkable. He, however, was a genius in a much bigger and wider sense. He was endowed with an uncommonly vigorous mind of exceptional power and originality; in consequence he had sufficient independence of thought to look at his subject in its broadest aspects and to arrive at his own conclusions, even though such were at variance with accepted public opinion at the time.

His careful, apparently meticulous methods which required such minute attention to detail, and included the planting of single grains of wheat by hand and the harvesting of the resultant plants separately, caused him to be regarded by some as a faddist. His method of distinguishing the plants which he had crossed by small strips of coloured calico gave to his breeding plots in the small field below us an appearance which caused some of those who did not understand the man to place him in a category which might include the village idiot.

It was inevitable that a man of his mental calibre, so much beyond public thought at the time, should be misunderstood before some of his aims were achieved. Even some of his relatives failed to understand his objective. One of them who thought him a faddist once asked: "Is this work of Farrer's really any good?" Fortunately at this time one of his early successes, "Bobs", had given evidence of its great economic value in the Gunnedah district, and a very convincing and emphatic reply was possible.

The essential technique for producing new varieties, e.g., the planting of single grains by hand at regular distances apart, was in such violent contrast to farming practice where there was an ever increasing urge for mass planting and mass harvesting, that they were anathema to some of his colleagues who were more accustomed to farming practice than to scientific method. In consequence, his methods earned for him the passive and even open hostility of one or two of his colleagues; one of these even went so far as to say that he would like to put a fire stick in Farrer's wheat plots.

In striking contrast to this opposition was the encouragement in his work which he received from his wife, née Nina Fane De Salis, whom he married in 1882. Mrs. Farrer took a keen interest in his work, encouraged and stimulated him. Though unfortunately childless, the union was an extremely happy one. She was a typical Australian country woman, a gentlewoman beloved by all in the district—and its queen. She was an ideal hostess to dispense that open-house hospitality associated with "Lambrigg".

Farrer's Successes.

With regard to his own work, Farrer was the most modest of men, and on the other hand most generous in acknowledging the assistance to his work rendered by others. He would be the very first to pay a tribute to the assistance given to him by his friends, Frederick Bicknell Guthrie and Richard W. Harris. Just as Farrer pioneered the production of improved varieties in Australia, so Guthrie broke new ground in connection with cereal chemistry, while Harris was responsible for the beginning of our experimental milling technique. As the result of the assistance of these two co-workers, Farrer was able to make very distinct advances in connection with the improvement of the baking quality of our wheats. Maximum success in this connection was the production of "Comeback". It is still the peer of the world's best strong or hard wheats and the standard of baking excellence in Australia. Its production was an inspiration to Farrer's successors to combine baking excellence with those qualities of prolificacy and other field characteristics which Farrer's work now requires that the Australian standard varieties shall possess. Success achieved in this connection can be measured by the popularity in the milling and farming worlds of varieties like Dundee, Ford, Nabawa and Bencubbin.

Farrer was too modest to name any of his successes after himself. Much against his will, his friend and co-worker, Hugh Pye of Dookie, gave the name of Rerraf to one of his own productions. This, when spelt backwards, gives us Farrer. Unfortunately this variety had only a short life.

To a variety which at the time of his death was rapidly growing in favour as a rival to Federation, Farrer named "Bayah". This was the pet

name by which Mrs. Farrer was always called by her niece Vera. It is to be regretted that the popularity of this variety did not persist.

Farrer's success was not adventitious. It was achieved as the result of planning and working towards a definite and preconceived objective. His success was a veritable triumph for scientific research and patient and careful investigation. The most spectacular of Farrer's successes was the variety Federation. The production of this variety was the result of a deliberate attempt to produce a variety with short straw especially suitable for Australian methods of harvesting with the stripper. A quarter of a century after the death of Farrer, it was still the most prolific and popular variety in Australia. The colour of the "Federation" ears was a characteristic shade of bronze, and so extensively was this variety grown that the colour of our harvest fields had been changed from the proverbial golden one to one of dull bronze.

Farrer's greatest achievement, however, was not that he produced many improved varieties suitable for Australian conditions, but rather that in Australia he lit the torch of wheat improvement so that others might be stimulated to carry it forward. There is much evidence that this has been done, but none more striking nor convincing than the record of the work of Dr. W. L. Waterhouse, the first Farrer Research Scholar. Seeing that the original inspiration for Farrer's work arose from the losses due to the ravages of rust, it is singularly appropriate that Dr. Waterhouse should have devoted himself to the study of cereal rusts and that he should have embodied the successful results of his painstaking studies in his presidential address to the Agricultural Section of the Australian and New Zealand Association for the Advancement of Science now in session at Canberra. It was at a meeting of this Association that Farrer first, 40 years ago read a paper in which he described his work and indicated the special difficulties he was experiencing because of the paucity of reliable information regarding wheat rusts. Farrer would have gloried in the successful achievement of Dr. Waterhouse and have recognized that his work is a noteworthy and striking contribution to the solution of the Australian rust problem.

Desire for Service.

Farrer was dominated by the desire for service. He wanted to be of use to the community. This is forcibly illustrated by the following incident. When the variety "Bobs", which was probably the earliest of his successes, was gradually growing into public favour, I said to him: "You must be very proud of the success achieved by 'Bobs'." "Oh, no", he replied. "Do you know why I commenced this work? It was because I wanted to think that when I died my life had not been wasted."

It is not generally known that Farrer refused a considerable fortune so that he might continue to render service. A very wealthy uncle gave him

the alternative of leaving Australia and returning to him in England or be disinherited. Fortunately, for Australia, he chose the latter and was literally "cut off" with a shilling.

Physically, Farrer was far from robust. As a young man he came to Australia suffering from pulmonary trouble, and to such an extent that a leading insurance office refused him a policy and considered that his expectation of life was less than 20 years. With suitable diet and living conditions he kept the grim reaper at bay for almost 40 years. His death was sudden, although not unexpected. For some time before his death he knew how slender was his hold upon life, but this did not cause him to save himself; it seemed to spur him on. He thought he might have had another 10 years in which to work, and felt that in those 10 years there were great possibilities. He died not from T.B. which threatened him as a youth, but from Angina Pectoris. He died as I feel he would have wished to die, right in harness. He was stricken down with a half finished letter in front of him; he was busy preparing for the coming season's work after having just completed that of the past season. What a suitable crown to the career of a successful and unselfish worker who loved his work and whose sole object in undertaking it was that when he came to die "he might think his life had not been wasted".

At his own request, his eternal resting place is on this hilltop overlooking his former home and scene of his labours. The outlook, as was his in life, is broad, free and bold. The distant, rugged and everlasting hills are typical of the enduring character of his work.

"Peace hath her victories no less renowned than war", and so today we do homage to the memory of a Conqueror.

Survey of Rural Potentialities in Relation to Population Capacity

I. THE DETERMINATION OF AGRICULTURAL AND PASTORAL RESOURCES IN SOUTH AUSTRALIA.

By

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The Agricultural Sciences Club of the Waite Institute, in October, 1936, undertook the somewhat ambitious task of estimating the "Potential Population Capacity of South Australia", as determined from the agricultural point of view, and according to the practical and scientific knowledge then available. The principal objective was to assess, at first in a preliminary way, the extent to which agricultural and pastoral production could be increased in the light of the soil and climatic conditions known to obtain, and as a result of improved agricultural methods. The restriction was made that only those forms of production and methods of improvement known to be economically practicable at the time could be considered; apart from this, economic factors were to be disregarded. From the increases in production indicated by a survey of this type, it appeared likely that a fairly reliable estimate of the possible future population of South Australia could be obtained.

It was felt that in view of the diverse and unqualified estimates made from time to time concerning the capacity of Australia to absorb an increased population, the Club would perform a service in arranging for a discussion based on the knowledge accumulated in recent years regarding this particular State's agricultural possibilities. It was hoped, furthermore, that in the event of the discussion proving fruitful, the question might be taken up by the Institute of Agricultural Science, with a view to the ultimate assessment of Australian agricultural resources as a whole.

Results of Discussion by Agricultural Sciences Club, Waite Institute.

The discussion was opened by Dr. A. E. V. Richardson, who dealt with the general question of agricultural development in South Australia, with particular reference to the wheat and pastoral industries. Dr. H. C. Trumble next spoke in terms of the capacity for improved pasture production in those areas of the State receiving more than 15 inches of mean annual rainfall. Mr. A. G. Strickland discussed the future possibilities of the State in regard to the production of fruit and wine; and Professor J. A. Prescott dealt with the irrigated and irrigable areas. Finally, Mr. L. J. Cook, who

has had extensive experience of pasture management in the south-east of South Australia, spoke on the possibilities for development in this portion of the State.

The above papers were followed by a general discussion, in which such questions as the standard of living and the ratio of the number of holdings to the total urban and rural population were brought forward. The general purpose of this particular discussion, however, was to assess the capacity of the land entirely in terms of primary production, and questions relating to the secondary industries, the standard of living and marketing problems were at the time excluded. The broad conclusion was reached that in the region of less than 15 inches of rainfall, involving a mean effective rainfall season of less than six months, with summer drought for more than six months of the year, and occupying 92 per cent. of the State, there was little likelihood of any further expansion in the rural population, and that the so-called empty spaces of the map were about as fully occupied as they were ever likely to be. In the better rainfall areas of the State there was room for a substantial increase in the rural population; and if all the land in the State were put to its highest and most intensive use, it appeared that the population might ultimately be increased to two and a half times its present total, though even this estimate was regarded as optimistic rather than otherwise.

Development of Topic by the Institute of Agricultural Science.

The topic was further developed a month later at a general meeting of the S.A. Branch of the Australian Institute of Agricultural Science in November, 1936. Dr. Richardson reviewed the material submitted at the October meeting of the Agricultural Sciences Club; while Mr. J. A. La Nauze, Lecturer in Economics at the University of Adelaide, and Mr. G. J. Seaman, of the Auditor-General's Department, South Australia, contributed papers on "Population Trends", and the "Numerical Relation between Agricultural and Total Populations",[2] respectively.

In his Presidential Address[1] to the first General Meeting of the A.I.A.S., held at Sydney in January, 1937, shortly after the October and November meetings described above, Dr. A. E. V. Richardson described the results that had been brought forward in South Australia, and suggested that "the various Branches of the Institute might perform a useful service to Australia by attempting, with the aid of its own members and with the collaboration of economists and geographers, to survey the agricultural resources of their State and assess the probable future capacity of the various classes of lands when put to their highest use. A large amount of information on the quality of land in settled districts is already available in the Lands Departments, taxation offices and banks, and if this could be collated

by a group of research workers, it might prove of considerable value in assessing the future productivity of such lands."

The Institute as an entity has taken up its self-imposed task with a worthy enthusiasm, and all Branches appear to have considered the problem in some detail. The progress reports submitted at the second General Meeting held at Canberra in January, 1939, indicated, however, that in the majority of cases comparatively little practical advancement had so far been made with the project; and as a result of a request made at that meeting the preceding notes and the following details of the methods employed for assessing maximum productivity in South Australia are given.

Main Objectives and Type of Data Utilized.

It should again be stated that before any reliable estimate of population capacity can be undertaken, an accurate determination of maximum agricultural and pastoral resources must be made; and the first step, as indicated by Dr. Richardson in his address, should be along the lines of a national inventory, supplemented to the utmost degree by the practical and scientific experience now available. Much of the information required is already in the hands of individual workers or has yet to be gleaned by the future researches of individuals, working singly or as members of a team. The plan of the Branch is to acquire, assemble and collate the evidence brought forward by these individuals and to indicate where additional research is necessary.

It should also be pointed out that the evidence brought forward at the meeting of the Agricultural Sciences Club at Adelaide in October, 1936, had been accumulated largely as a result of investigations commenced some years earlier, and that the methods of analysis adopted might have to be modified considerably for other portions of Australia, where natural conditions of soil, climate, topography or variability are widely dissimilar; or where field experimental work has not yet advanced sufficiently to enable probable future production to be assessed.

Methods of Investigation.

Three methods have been employed in South Australia for the purpose of assessing rural potentialities. These are: (1) the production survey, by which the present condition of production, as applied to the main commodities, e.g. wheat, sheep, cattle, and such forms of improvement as seeded pasture establishment, are determined from time to time and the main trends determined; (2) the analysis of soil and climatic conditions and the delineation of natural edapho-climatic zones; (3) the experimental method, by which field investigations designed to determine the possible degree of improvement over and above present production are carried out. This

latter, to be fully effective, must be related to particular sets of conditions as represented in a generalized way by different edapho-climatic zones.

The following details apply to the methods employed by the author[3][4] in connection with ecological studies of the agricultural areas of South Australia, which commenced about 1930; and these are given with the reservation that the estimates derived as a result of this work formed only one of the five independent estimates submitted at the original discussion in October, 1936. These estimates, however, were found to give a surprisingly good general agreement, although mutual discussion of the problem had deliberately been avoided prior to the meeting. Furthermore, practical experience of the two subsequent years has not indicated that the general findings of 1936 should be substantially modified.

Production Surveys.

For the making of production surveys, the official State Government statistics relating to production have in all cases been utilized. Criticism of the accuracy of these is sometimes made on the grounds of fallibility on the part of the individual producer, on whose personal returns the accuracy of the final estimate depends. The validity of this type of data has, however, been fully substantiated by critical examination in the United States; and a good many years' experience with the method in South Australia has tended definitely to endorse the American view.

The hundred has been invariably employed as the unit; this, generally speaking, occupies an area of approximately one hundred square miles and is a subdivision of the county. The county itself is far too large a unit for good comparative work, and units of smaller size than the hundred are in general unnecessary and may even be misleading. In the case of the northern pastoral areas of South Australia, over which neither counties nor hundreds exist, records for each pastoral station were kindly made available by the Pastoral Board of South Australia. In general, a run of three seasons is regarded as a minimum; a period of five years is to be preferred. For special purposes single years may be sufficient, and in one case a comparison was made of wheat and seeded pasture immediately prior to and following the depression of 1930-33.

The main comparisons that have been made on a hundred basis are as follows:

(i) Production records	×	(ii) Environmental criteria
1. *Livestock* (*a*) Sheep (*b*) Cattle (*c*) Horses 2. *Wheat* (*a*) Acreage (*b*) Mean yield per acre 3. *Seeded pasture* (*a*) Acreage	×	A. *Natural climax vegetation* B. *Generalized edapho-climatic types* C. *Intra-zonal soils*

Definition of Soil and Climatic Types.

The most difficult problem for some years has been that of obtaining a cogent single value measure of the prevailing climatic conditions. The figures for both annual rainfall and the arbitrarily chosen April-October rainfall presented very obvious deficiencies, particularly for surface rooting plants such as subterranean clover. The well-known Goyder's Line had been employed more widely as a guide to settlement than any average rainfall figure; and there apppeared to be no obvious relationship between Goyder's Line and the quantity of rainfall, either total or seasonal. The discovery of a relationship between monthly rainfall and free water surface evaporation, capable of providing a satisfactory measure of the effective rainfall season and the amount of influential rainfall, supplied the key to a better understanding of the interactions between climate and vegetation in South Australia. The length of the rainfall season was found to exercise a major controlling influence over natural vegetation, crop and herbage plants in this State; and the well-known Goyder's Line represented, over much of its length, a mean annual rainfall season of approximately five months and a mean drought period of seven months.

Following the separation of natural climatic zones on this basis, and the correlation of the newer climatic measures with soil types and vegetation, it became obvious that there were a number of natural edapho-climatic zones in South Australia, their various features being as indicated in Table 1.

The distinctions between zones 7, 8 and 9 are not so rigid as they appear in the table; in the original paper an additional marginal zone was introduced, and in this zone the southerly limits of shrub steppe, the 5 months isochrone, and 5″ isohyet for influential rainfall and the 10″ annual isohyet tend rather to congregate.

Importance of Field Experimental Work.

The delineation of contrasting edapho-climatic types, as indicated above, is not in itself sufficient for the determination of productive capacity; nor does the super-imposition of recorded production statistics alone solve the problem. The remaining link in the chain of evidence necessary is a fairly comprehensive investigational programme aimed at assessing the improvements in production attainable within each edapho-climatic zone. This may be effected by intensive studies on representative sample areas or experimental centres. These investigations should be both fundamental and strictly ecological in interpretation, but should also be closely related to the practical experience of the producer and of the advisory officer. It is unnecessary at this stage to consider the type of information that has become available as a result of work of this nature in South Australia, but sufficient data have been obtained to indicate with a good degree of reliability the extent of improvement possible in the better rainfall areas of this State.

TABLE I.

Features of Natural Edapho-Climatic Zones in South Australia.

Zone	Edaphic Type.	Climax Vegetation.	Mean Rainfall Season. (Months.)	Mean Influential Rainfall. (Inches.)	Mean Total Rainfall. (Inches.)	Main Forms of Land Utilization.*	Herbage Plants Suitable for Seeded Permanent Pasture.
1	Podsolised sand.	Sclerophyll forest.	>9·0	>25	>28	Livestock husbandry.	Subterranean clover, white clover, fog, *Agrostis* spp.
2a	Volcanic ash.	,, ,,	,,	,,	,,	Intensive farming, including dairying.	White and strawberry clover, perennial rye-grass, cocksfoot, *Phalaris*, *Poa pratensis*.
2b	Friable black clay.	Open grassland.	,,	,,	,,	,, ,,	,, ,, ,,
2c	,, ,,	—	—	Irrigation.	—	,, ,,	,, ,, ,, *Paspalum*, fog, prairie.
3	Podsolised sand and laterite.	Sclerophyll forest and savannah (*E. leucoxylon*).	7·5–9·0	15–35	20–43	Livestock husbandry.	Subterranean clover, Wimmera rye-grass, *Phalaris*, perennial rye-grass.
4	Friable black clay.	Open grassland.	,,	18–25	22–28	,, ,,	Strawberry clover, black medic, lucerne, *Phalaris*, Wimmera rye-grass.
5	Deep sands.	Heath and scrub.	6·0–7·5	10–18	15–22	,, ,,	Lucerne, early subterranean clover, evening primrose, *Phalaris*, Wimmera rye-grass.
6	Red, brown and grey soils.	Savannah (*E. odorata*) and high mallee.	,,	,,	15–25	Cereal cultivation and livestock husbandry.	Lucerne, early subterranean clover, *Phalaris*, Wimmera rye-grass.
7	Mallee soils and quartzitic soils.	Mallee and dry savannah (*E. odorata*).	5·0–7·5	8–15	12–20	Cereal cultivation, with sheep and cattle.	Lucerne, evening primrose, Wimmera rye-grass, barrel medic, with early flowering ephemerals.
8	,, ,,	Mallee.	5·0–6·0	5–12	10–17	,, ,,	,, ,, ,,
9	Semi-desert and desert soils.	Desert scrub, shrub steppe and mallee.	<5·0	<5	<10–12	Purely pastoral, with sheep and cattle.	—

* Agricultural and pastoral only.

Example of One Independent Estimate of Maximum Productivity.

In conclusion, a summary is given of the author's original estimates of the numbers of sheep capable of being carried in South Australia, assuming that no other form of production occurred and all available land were improved in the light of existing knowledge and to the limit of existing economic practicability. Again, this was one only of five independent estimates, but the result obtained was not widely dissimilar from the general result of all five. The objective of expressing all available productivity in terms of sheep was to attain a uniform factor for the entire State. The sheep factor can readily be converted to cattle of different types or to wheat or other crops where necessary.

The figures when first calculated were not taken very seriously; they are more than guesses, however, and the more one has looked at them, the more realistic and significant they appear to have become. Future work of a more detailed and critical nature may result in considerable modification; but for the present they provide a working basis for general criticism and revision, and at the risk of incurring the rebukes of posterity they are given, as originally prepared, for what they should happen to be worth.

TABLE 2.

Probable Grazing Capacity of South Australia, in Terms of Sheep.

Type of Country.	Area. (Acres.)	Sheep per Acre.	Capacity in Sheep.	Area to give 400 Sheep (or equivalent) (in Acres).	Number of Units.
1. Irrigated land ..	20,000	10	200,000	40	500
2. S.E. heavy black soils and volcanic soils ..	500,000	4	2,000,000	100	5,000
3. S.E. light textured soils	3,200,000	2½	8,000,000	160	20,000
4. Mt. Lofty Ranges, Kangaroo Is., etc., clover soils	2,000,000	2½	5,000,000	160	12,500
5. Heath and scrub sands	5,000,000	1	5,000,000	400	12,500
6. First class cereal land	5,000,000	2	10,000,000	200	25,000
7. Second class cereal land	5,000,000	1	5,000,000	400	12,500
8. Third class, marginal land and purely pastoral land	(347,700 sq. miles)	—	5,000,000	—	12,500
Total, 1–7	(32,370 sq. miles)	—	40,200,000	—	100,500
8	(347,700 sq. miles)				

In the estimates in Table 2, the sheep per acre factor was fixed purposely at a lower value than much of the land in each zone was known to be capable of carrying, in order to allow for unproductive areas and an inevitable proportion of inefficient producers. Moreover, portions of the first four zones would probably yield a considerably greater return per acre from intensive cropping than from the maintenance of sheep. On the other hand, certain losses would occur from wastage and erosion. On the whole, the figure of approximately 100,000 holdings was regarded as conservative rather than unduly optimistic.

The production unit of 400 sheep was considered by some to be too low. This, however, would be equivalent to about 50 cattle, and should, under average conditions, return a net income of rather more than the basic wage. We must be guided by the fact that we are considering average conditions of production and not those of the more progressive producers with whom we tend most to be associated in experimental or advisory work. Should the average level of production per unit rise, it is almost certain that the ratio of production units to total population will fall, resulting in a compensatory effect.

Estimation of Population from Production Capacity.

The mean of the various estimates attempted gave the figure for the maximum number of holdings as 114,000. Since the basis of the estimates was the "one-man" property, the attainment of the maximum intensity of settlement would be followed by a fall in the number of employed workers and of the present ratio (1·7 : 1·0) of rural workers to number of holdings. Allowing for the inevitable employment of such workers as shearers, fruit pickers, etc., a ratio of 1·3 : 1·0 was tentatively adopted, together with a ratio of 10·9 : 1·0, as provided by the 1933 census for the ratio of total population to rural workers. This gave a figure of 1,616,000 persons as the maximum population of South Australia, a figure subject to revision after the collection or study of additional data. This potential population bears a ratio of 2·8 to the present population of 581,000, as revealed by the 1933 census. It is highly probable that very different ratios will be obtained for different States; but there seem to be ample grounds for believing that the various estimates of 100-200 millions for Australia as a whole are fantastic, and greatly in excess of the true capacity of the Commonwealth.

References.

[1] Richardson, A. E. V.: Jr. Aust. Inst. Agr. Science 3: 3-18, March, 1937.
[2] Seaman, G.: Jr. Aust. Inst. Agr. Science 3: 19-24, March, 1937.
[3] Trumble, H. C.: Jr. Agr. S. Aus. 38: 1460-1487, July, 1935.
[4] *Ibid.*: Trans. Roy. Soc. S. Aus. 61: 41-62, 1937.

II. SUMMARY OF METHODS AND PROGRESS IN VICTORIA

By

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This record is written in the hope that it may be of help to Branches of the Institute of Agricultural Science which have not yet been able to proceed very far with the project. Mistakes have been described as well as progress. It should be noted that the account is devoted to technique rather than to policy, and while it represents the experience of the author over two years of intermittent work on the survey, it may not necessarily represent the views of the Victorian Branch.

Initiation of the Survey.

The pioneer work carried out by the South Australian Branch formed the background of the Victorian survey, though not the basis, due to lack of suitable data regarding soil and climate and to the rather more diverse agricultural and pastoral system of Victoria. Moreover, this same complexity made a more detailed survey desirable. A sub-committee of six was appointed to investigate methods of attacking the problem. Professor S. M. Wadham made it possible for work to be undertaken at the School of Agriculture, University of Melbourne.

General Principles Adopted.

Certain general principles were decided upon to assist the conduct of the survey. These were as follows:

1. *Production Records.*—The official statistical returns should be collected into a suitable form in order to give the present position in regard to production.
2. *Climate.*—The principal climatic zones of Victoria should be delineated on the basis of the most suitable factor or factors.
3. *Soil.*—An attempt should be made to construct a generalized map of soils, such as has been prepared for South Australia.
4. *Zones of Productivity.*—Victoria should then be divided into zones according to climatic and soil factors, and those Institute members most familiar with each district should be asked to assign to each zone a reasonable standard of maximum productivity, based on the latest official returns of production levels, on practical observation, and on the results of field experimental work.
5. *Economic and Marketing Factors.*—It was felt that any deep consideration of economic factors should be postponed as long as possible. (See Section 2 of the final summary.) There also seemed no point in encountering trouble at this stage over questions of converting production information into figures of population.

Progress of the Survey.

The work which was commenced with these principles as a basis, is described below. As it proceeded, certain modifications and additions to the original plan were found necessary.

Production Records.—Maps of Victoria were constructed, showing by counties each of the chief forms of product by the proportional square method (three years' average). These were printed and made available in booklet form by courtesy of the *Age* newspaper, and were in large demand from the public.

There are 37 counties in Victoria, and for the purposes of the survey these maps lacked detail. Consequently maps were made of the distribution of wheat, oats, barley, sheep, dairy cattle, and beef cattle on the parish basis for the year 1936-37 only. These also have been published by the *Age* in booklet form. There are approximately 1800 parishes in Victoria, each of an average area of 25,000 to 30,000 acres.

Climate.—A considerable amount of time was devoted to studying various single climatic values, such as the Meyer ratio, with the object of finding a satisfactory measure for the climatic mapping of Victoria. Particular attention was devoted to those involving saturation deficit or evaporation, and a number of relations were tested—in some cases by comparison with the yields of pasture obtained from field trials conducted at various centres by the Victorian Pasture Improvement League. However, no really satisfactory relation was decided upon, and pressure of other work caused this investigation to be discontinued before finality was reached. The principal difficulty was due to the wide differences which exist between the wet oceanic climate of the southern part of the State and the dry continental inland climate. To deal adequately with both of these a fairly comprehensive relationship is required, and for New South Wales a further complication will be the intrusion of semi-tropical conditions and summer rainfall.

A stocktaking at this stage indicated that Victoria was not yet at grips with the problem, and the difficulty of planning ahead the detailed scheme for attack on a completely new problem was realized. Actual work in the field appeared the only solution, and the sub-committee decided to test various methods in the County of Burke, which includes Melbourne and is, therefore, easily accessible.

The parish of Holden, of approximately 20,000 acres, was selected, and production data collected from the Government Statist were assembled on sheets with columns for present, additional, and potential production of each type of crop and stock; the parish was visited with the object of seeing if it were possible to complete the latter two columns after inspection in the field.

Here the defects of an approach based purely on production records became apparent, and in effect the parish was found to be too *small* a unit when considering many forms of production. For instance, a large sheep property may overlap one or more parishes, and yet all its stock and crops are necessarily returned as being in the parish in which its homestead lies. In the case of intensively settled areas the error may become negligible, but for this and other reasons production records alone should be treated very cautiously.

However, inspection in the field was continued by observation and discussion with farmers, and in a period of three hours an excellent idea was gained of the prevailing soil type and the type of production level of farming and degree of improvement possible for the parish. It was found quite practicable to record these observations with any desired degree of detail on the relevant section of the Military Survey Map, scale one inch to one mile, supplemented where necessary by notes.

Present Situation.

The Victorian survey is now at the stage indicated above. It is felt that progress has been made, and some false scents have been abandoned. The production maps constructed, though of doubtful utility for the survey, have a definite value as pictorial summaries of present production. An outline of projected future activity in Victoria is as follows:

Climate.—The method for the delineation of climatic zones in Victoria and southern New South Wales, upon which Dr. H. C. Trumble, of the Waite Institute, is at present engaged, appears extremely promising for use in the survey. Pending publication of his work, nothing further is being done in this direction in Victoria.

Soils.—It seems likely that personal inspection of large areas by a few workers will be impracticable, although such inspection may be necessary for small areas to plan the treatment of the various zones. But accurate details of soil types and their distribution are lacking for Victoria, and if personal inspection of most of the State is to be avoided, this deficiency must be remedied. Consequently it has been suggested that Victorian soil experts be asked to define what they regard as the chief soil types from a broad agricultural point of view. Armed with these definitions, members of the Institute familiar with certain districts can then proceed to outline the boundaries of such regions in their districts, thus arriving at a broad soil map of the State.

Zones of Productivity.—Further work is proposed upon the field survey of parishes. Then with the help of data and experience gained therein, it should be possible for the Victorian Branch as a whole to combine the individual knowledge and experience of district officers with the climatic and soil data referred to above, and ultimately to arrive at potential

productivity on a fairly detailed basis, the exact terms of which have yet to be decided upon.

Two limitations to the field survey of parishes should be noted: availability of military survey maps, and season of the year. At the time of writing, any such work is impossible in many parts of the State due to lack of vegetation.

It is hoped that this record of experience in Victoria will prove of use to other States, and assist them to select methods suitable for their particular conditions. The survey is undoubtedly a difficult one, but a satisfactory conclusion should be within the bounds of realization.

Some of the main points, the observance of which should facilitate the work, are summarized below:

1. It is suggested that the type of approach which is based purely on official records of production should be avoided as far as possible, particularly if accuracy is to be achieved.
2. The early consideration of economics seems undesirable, since the inevitable controversy must endanger uniformity of approach to the survey at its present immature and tender stage; and the economic future is liable to rapid and unpredictable changes. Work involving economic theory should be the superstructure rather than the keystone of the survey, and we should not lose sight of the possibility that this superstructure should be applied by specialists in economics rather than in agriculture. That the project can proceed with the minimum of economic considerations is shown by the South Australian survey.
3. In assessing potentialities for production, the results of field experiments should be fully utilized, as they provide "stop-press" information on what can be done under various conditions.

   The accumulated experience of the various district officers should be of great assistance, and close co-operation between those making the survey and experimentalists and advisory officers seems most necessary.
4. It is suggested that consultation between Branches is desirable on certain points where uniformity should be obtained as early as possible, i.e., soil or climatic classifications, standards for conversion of sheep, cattle, etc., into stock units, economic size of properties, stock and crop values, types and intensity of erosion,* etc.

* Soil erosion has been suggested as a problem to which the Institute might well devote some of its energy and influence. For such work, accurate knowledge of the extent and severity of erosion in various districts is essential, and it should be possible to take advantage of any district agricultural surveys to collect this type of information. Reference is made here to the erosion map of Australia produced by the Bank of N.S.W. (Circular, Vol. IX, No. 1, Jan., 1939).

TECHNICAL NOTES

RESPONSE TO COPPER AS A FERTILIZER ON CERTAIN SOILS IN WESTERN AUSTRALIA.

The value of various "minor" elements in addition to the usual fertilizer ingredients has been proved in a number of instances in Western Australia. Zinc has produced spectacular responses with pines and has proved of value in citrus disorders; manganese has been used to control grey speck disease of cereals and promises to make possible the use of certain marly marshes in the Albany district for the growth of vegetables and potatoes; copper salts have proved beneficial in the case of certain forms of dieback and other disorders of fruit trees and the use of copper sulphate is reported to have greatly improved the growth of oats at Dandaragan where stock diseases related to copper deficiency are being investigated. Also, at Dandaragan, typical copper deficiency symptoms have been observed in oats, wheat and barley.

Perhaps the most spectacular plant responses to copper salts have been observed in the Albany district on peaty soils and sands, and on sandy lateritic soils at Wagin.

Experiments in the Albany District.

Experiments with minor elements, commenced in the Albany district in 1937, met with immediate success. In an experiment on an acidic black muck (pH 4·2) at Bornholm a mixture containing copper, manganese, zinc and magnesium sulphates each at the rate of 20 lb. per acre, in addition to a "complete" fertilizer, gave a 40 per cent. increase in yield with potatoes. Oats, sown on the same area following the digging of the potatoes, made spectacular growth on the sites of the minor element plots and the symptoms suggested that copper was the active ingredient. Weighings indicated that the treated areas would yield about 11 tons of green material per acre, while only 2 tons could be expected from the land which had not received minor elements. The succeeding potato crop, sown in December, 1938, also showed a marked response to the residues of the minor elements. A more critical experiment of factorial design commenced on adjacent land of the same type in December, 1938, showed that the response was due primarily to copper.

The effect of copper on potatoes is readily observed in the tops and tubers: the foliage is more vigorous and the leaves a paler green colour than in the controls; the stems are thicker and more erect and there is a strong development of branches and subsidiary stems; flowering is more profuse and prolonged and the tubers of superior quality. It has been observed that the eyes are stronger and more deeply set, and the effect is transmitted to the succeeding crop.

The symptoms of the oats resemble those described in the literature.

These results with potatoes and oats so impressed farmers of the district that several tons of bluestone were used during 1938 on a variety of crops and soil types. In the majority of cases very satisfactory responses were obtained with dressings ranging from 8 to 15 lb. per acre. On a brown sandy soil of a karri hill, barley was greatly improved, garden peas produced excellent well-filled pods instead of the usual "puff-boxes" or empty pods, and onions made satisfactory growth for the first time. An experiment on an adjoining farm on virgin acidic wet heath country showed that, if the surface mat of fibrous material were broken up and burnt, an excellent stand of subterranean clover, cocksfoot, prairie grass and other pasture species was obtained if dressed with copper sulphate. Without copper sulphate, no growth, except of a little *Lotus major* and Yorkshire fog, was obtained. Establishment was achieved without the use of superphosphate. It was further observed that on this type of land Yorkshire fog requires copper dressings to maintain a sound root system and a firm crown.

At Lake Saidie, on sandy swamp land deteriorated as a result of two or three successive crops of potatoes, satisfactory crops of cabbages and potatoes were produced this summer where copper sulphate was used, whereas without copper sulphate almost complete failure resulted. On another farm, Wimmera rye grass grew on a type of sandy soil only where copper sulphate had been used.

Response to Copper on Light Lands—Particularly Lateritic Gravelly Sands at Wagin.

Striking response to copper sulphate, applied at the rate of 20 lb. per acre, was obtained over portion of an area of 12 acres under experiment with various minor elements, and some response was evident over the whole of the copper treated plots.

Many years of agricultural experience persuaded one of the writers (A.M.S.) that the Great Southern soils of lower fertility were lacking in some factor or factors that were present in the red-brown soils associated with the basic dykes which occur through this region. Stock grazing on the poorer classes of country do not make the growth or carry the bloom of animals grazing on the red-brown loams which are the bases of much of the agricultural development of the Great Southern.

To make qualitative observations on the effects of some minor elements on some representative types of light land, an exploratory experiment* was laid down in May, 1938, using duplicated plots of 0·43 acre running across

* The fertilizers were provided through the courtesy of Cuming Smith, Mt. Lyell Farmers Fertilizers Ltd.

a shallow valley between two lateritic ridges. Soils ranging from poor lateritic gravelly sands to cementy sandy loams were crossed by the plots, and the responses to copper, manganese, zinc and iron as commercial sulphates, to cobalt chloride and to borax, observed.

The area has been cleared and farmed for 25 years.

The greatest responses were obtained from the lateritic gravelly sands where copper was applied. No other "minor" element had any observable effect. Although this soil type had failed to mature a crop in 20 years' experience, with copper the yield of wheat would be equivalent to over 25 bushels per acre.

Nabawa wheat was sown on clean fallow in good condition on May 20th and 21st, 1938.

One month after sowing, the copper treated strips exhibited a much brighter and healthier green than the other plots, but there was no other detectable difference. Borax (10 lb. per acre) and zinc sulphate (10 lb. per acre) had a deleterious effect. Similar observations were made one month later.

Three months after seeding, the copper treated plots were even more outstanding. Not only was the foliage attractively green, but the plants were more erect and appeared to have less dead and brown-marked leaves at the base than elsewhere. Plants were dug up from all plots for spectrographic analysis and it was apparent that the copper treated plants had made stronger root development. The biggest differences occurred on the gravelly sands near the lateritic ridges.

When examined in October, the wheat had headed and grain was forming. The copper treated plots were even more obvious as the wheat was standing up erect, level and strong throughout and was developing well-formed, well-filled heads. The other plots were very uneven, reflecting the variations in the soil. Whiteheads were particularly common on the poorer soil types.

At maturity, over the fairly small area of poorest gravelly soil, nearly all plants, except those treated with copper, failed to mature; the straw was a dirty grey-brown in colour and the glumes of the aborted ears pale. Even where there was no apparent difference in yield, on the better soil types of the valley it was noticed that the glumes of the heads in the copper treated strips were brown, while those on the other plots were pale.

Copper in combination with manganese and zinc was not superior to copper alone.

It is to be noted that the Wagin district experienced an abnormally low rainfall in 1938, recording only 12·7 inches. The average is 17·4 inches.

In contrast with these responses it must be stated that a similar range of minor elements has been applied to wheat on light soils at Cleary and the Wongan Hills Research Station without such beneficial results being obtained.

Quantitative work is being arranged with a view to determining the soil types that will respond to treatment with minor elements, the optimum rates of application and the lasting value of the dressings.

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Department of Agriculture, Western Australia.
A. M. Stewart,
Institute of Agriculture, University of Western Australia.

The Australian Institute of Agricultural Science

THE NEW PRESIDENT.

Professor Robert D. Watt, Dean of the Faculty of Agriculture in the University of Sydney, was installed as President of the Institute in the course of the General Meeting at Canberra in January. The appointment carries with it the congratulations and goodwill of all members of the Institute, for, as the senior Professor of Agriculture in the Commonwealth, Professor Watt has earned the respect and esteem of agricultural scientists far and wide—particularly on account of the excellence of the broad, yet detailed, system of training in agricultural science which he instituted at Sydney University when appointed to the Chair in 1910, and which has been maintained to this day.

Robert Dickie Watt was born in 1881 in Ayrshire. He was educated at the West of Scotland Agricultural College, the Scottish Dairy Institute and the University of Glasgow, and secured the M.A., B.Sc., N.D.A. and N.D.D. with highest honours. As Carnegie Research Scholar, he undertook chemical investigations at Rothamsted in 1905-7, and subsequent to holding the position of Chief

Chemist in the Transvaal Department of Agriculture, was appointed to the Chair in Agriculture at Sydney.

Professor Watt is Chairman of the New South Wales State Committee of the C.S.I.R., Chairman of the Executive Committee of the Australian National Research Council, a Trustee of the Public Library of New South Wales, and an executive member of many other scientific organizations. Formerly he was Chairman of the Murray Lands Commission, and of the Banana Bunchy Top Investigation Committee. He was a member of the Senate of Sydney University in 1934-5, and has been a keen Rotarian for many years.

SECOND GENERAL MEETING

The Second General Meeting of the Institute was held at Canberra City on January 9-10, 1939. Representatives from various parts of the Commonwealth were in attendance, and in the absence of the President, Professor S. M. Wadham, who had departed for England, the chair at both Council and General Meetings was occupied by Dr. B. T. Dickson. Enthusiastic discussion took place on the several matters which had to be considered, and it was generally felt that the meeting as a whole had proved eminently successful—despite the very intense heat. The way was opened up for renewed activity on the part of Branches in connection with the various Institute projects mentioned hereunder, and there is every reason to hope for a successful outcome in each of these matters.

In the absence of Professor Wadham, the retiring Presidential Address was read for him by Mr. G. W. Leeper, who made an admirable presentation of the thesis. As already indicated, Professor R. D. Watt was duly installed as President for the ensuing two years, and appreciative references were made of the service rendered to the Institute by Professor Wadham during his period of office. A dinner arranged at the Hotel Civic was well attended and proved a very happy conclusion to the functions at Canberra.

EXTRACTS FROM REPORT OF COUNCIL TO GENERAL MEETING.

Gentlemen: Your Council has pleasure in presenting its report covering the period from January, 1937, to January, 1939.

Operations commenced under the new constitution on 1st June, 1938, and the present is the report of the Council appointed under the relevant new Articles of Association. Although the Council has been in office for only seven months, it was considered desirable that a brief review should be made of Institute activities during the past two years. Your Council is glad to be able to describe this period as one of considerable progress.

Financial Position.

The financial position will be described to you in greater detail by the Hon. Treasurer in his report. This has already been perused by your Council and indicates that the financial position of the Institute is satisfactory. While general expenses, including those connected with incorporation, and Journal expenses have been rather heavier, these have been met, £200 has been placed on fixed deposit, and there is at present a balance of some £97 in the current account. Your Council has decided to make the grant for 1938 to the Branches at the rate of 5/6 in respect of each financial corporate member at 31st December. A further proposal in connection with Branch finance will be made later in this report.

Membership.

The membership of the Institute is now (30/11/38) 382 corporate members and 12 student members, the respective Branch totals being as follow:

	Corporate.	*Student.*
Victoria	97	1
New South Wales	89	—
South Australia	57	3
West Australia	47	5
Queensland	44	3
Australian Capital Territory	29	—
Tasmania	19	—
	382	12

The net increase in corporate membership during the period under review has been 61. The number of student members is, however, not so large as formerly.

Branch Activities.

The activities of the Branches have continued to expand in a most gratifying way. Special reference may be made of the Institute organization in connection with the recent visit to Australia of Dr. John Hammond, and of the success of the functions and meetings arranged by the Branches in the various States. Arrangements were made by the West Australian Branch for a report to be taken of Dr. Hammond's address to its meeting. This was excellently done and was later published in the C.S.I.R. Journal.

It would appear that the grant of 5/6 per member has been a fair contribution towards the cost of Branch activities. Your Council, however, has already indicated its willingness to give consideration to requests from any Branch for further assistance in connection with special or extended activities. Some Branches have difficulty in meeting expenses early in the year before subscriptions are received. In such cases, your Council proposes to place with the Branches an amount of £10 as a floating balance to ease this position.

As required by Article 26B, the necessary alterations to Branch by-laws have been made to bring them into conformity with the Memorandum and Articles of Association of the Institute.

The Journal.

The Journal of the Institute takes a very definite place in scientific publications in Australia, and may be expected to attract wider attention as time goes on. For this very happy result your Council has already expressed its appreciation to the officers concerned. This publication has been the creation of the Editor, Dr. H. J. Hynes, ably assisted by the Sub-editors in the various States. The business management was in the capable hands of Mr. E. T. Edwards until July, 1937, when he submitted his resignation prior to leaving for abroad. His successor is Dr. N. S. Noble, who has carried on most ably since that time.

Commencing with Volume 3, the Journal was enlarged to the size of 240 pages per volume, and the increased space has been well filled. Recently the policy of circulation of free copies of the Journal has been revised and arrangements made for copies to be sent only to a main library in each country and to well-known abstracting journals.

Potentialities and Population Survey of Commonwealth.

This matter was brought before the Institute by Dr. A. E. V. Richardson in his presidential address at the First General Meeting, when he urged that such a survey would be a valuable contribution which the Institute could make to the future planned development of Australia. Since that time events overseas have been such as to increase very greatly the urgency and importance of this project. Your Council has noted with great interest the progress that has been made with this work by the various Branches. (After presentation of reports at the General Meeting, it was agreed that Branches should continue with work on this project.—Ed.)

Plant Quarantine.

The subject of plant quarantine has recently engaged the attention of the Australian Capital Territory and Tasmanian Branches of the Institute. The former has submitted a statement of its views in regard to the type of organization which it considers should be set up, while an article on the same general topic by Mr. J. W. Evans, President of the Tasmanian Branch, has been published in the Journal. The rapid development in means of communication between the various countries of the world has raised new problems in quarantine practice, and your Council feels the subject well worthy of the attention of the General Meeting. (Following a full discussion, a committee was formed to deal with this project. Each Branch is to appoint a sub-committee comprising a plant pathologist, entomologist and weeds officer, to look into the position in their own State and make recommendations to the main committee.—Ed.)

Status and Salary Survey.

Two of the most important objects of the Institute are those stated in Clauses 2 (vi) and 2 (viii) of the Memorandum of Association, and the means of their attainment have had the consideration of your Council. As a first step it was felt that the present position of members of the profession in regard to salary and status should be determined. As the value of such information depended largely on its collection on a comparable basis in all States, a memorandum on the technique to be employed was prepared by the President and circulated to all members of the Institute. The progress reports of the Branch sub-committees dealing with this matter will be discussed later in this meeting. (Following discussion, a committee was formed to look into the position more closely.—Ed.)

General.

Following the result of the postal ballot on the accceptance of the Memorandum and Articles of Association, your Council proceeded to the legal incorporation of the Institute. This was finalized on 3rd October by the issue of Certificate of Registration No. 21912 under the Companies Act of Victoria, 1928. The Registered Office of the Institute is that of its auditors, Messrs. Cleveland, Son & Hislop, of 20 Queen Street, Melbourne. The total charges in connection with incorporation amounted to £38/6/-.

Arrangements have been made for a reprint of the Memorandum and Articles of Association for issue to all new members of the Institute. The order for printing has

been withheld until after consideration of the notice of motion for the alteration of Articles 3, 7 (i) and (ii), 8, 9, and 40 by this General Meeting. (These notices of motion were rejected by the General Meeting.—Ed.)

As the result of seven months of experience under the new Constitution, your Council expresses the view that the proxy system for Council meetings has worked well, and it trusts that the various Branches share that view. It wishes to express its thanks to the gentlemen holding proxies for the interstate delegates.

At the first meeting of the reconstituted Council on the 24th June, 1938, action was taken to re-elect the retiring President, Professor S. M. Wadham, and to re-appoint the previous office-bearers, namely, Mr. R. L. Twentyman (Hon. Treasurer), Mr. A. J. Vasey (Hon. Secretary), Dr. H. J. Hynes (Editor of Journal), Dr. N. S. Noble (Business Manager), until the date of this General Meeting. The appointment of office-bearers for the next year is, of course, the responsibility of our successors, but we wish, at this time, to record our appreciation of the services each has rendered to the Institute, and, if available, to recommend their re-appointment to their respective offices.

For and on behalf of the Council,

S. M. Wadham,

1st December, 1938. President.

REPORT OF THE TREASURER.

The financial position of the Institute has been further consolidated since the previous General Meeting. For the first part of the two-year period, the audited income and expenditure account for the year ended 31st December, 1937, showed a surplus of £56/16/3. The receipts and expenditure statement from 1st January, 1938, to 12th December, 1938, shows a credit balance of £97/8/1, which, in view of the £100 placed on fixed deposit during the year, indicates a surplus of roughly £30 for the year's operations. A substantial non-recurring charge met during the past year was the Incorporation Fee, but to offset this there has been an unusually large number of overdue subscriptions received during this period.

The cost of the Journal has been the biggest item of expenditure, but the *per capita* grant to the Branches has absorbed a considerable portion of the income. Approximately £75 was distributed among the Branches on account of subscriptions received during 1937, but owing to the number of late subscriptions received during 1938 a similar *per capita* payment for the past year will involve a considerably larger sum.

Although each year's account has included items which make a comparison of surpluses difficult, it would appear that whilst substantial credit balances were achieved on the first two years' operations, the results of the past two years suggest that expenditure is now gaining on the income. A comfortable bank balance has been accumulated, but more recently income has not sufficiently exceeded expenditure as to permit indulging in any considerable further expenditure.

It is to be regretted that a number of members have been rather lax in their payments of subscriptions, and it would greatly facilitate the work of the Branch treasurers and assist in the keeping of accounts generally if members would forward subscriptions well before the end of the year for which they are due.

R. L. Twentyman,

Hon. General Treasurer.

Current Notes and News

Unveiling of Farrer Memorial, Lambrigg.

The granite obelisk, erected in memory of William J. Farrer by the Federal Government on the highest eminence at Lambrigg, overlooking the picturesque old Farrer homestead and field laboratory, was unveiled by the Minister for the Interior (Mr. McEwen) on January 16, 1939, in the presence of a large assembly. Many overseas visitors to the Science Congress at Canberra were also present, including Sir John Russell, Professor R. H. Carr and Professor F. T. Brooks. The four Misses Desallis, of Michelago, were present to represent the family of the late Mrs. Farrer. Addresses were delivered by the Minister, Dr. G. L. Sutton, Dr. W. L. Waterhouse and Mr. G. W. Walker.

Following the unveiling of the Memorial, the headstone and flagstones for the nearby twin graves of Farrer and his wife were unveiled by Mr. A. T. Shakespeare on behalf of the Country Press Association, which body had donated the stones.

Winter School in Soil Science at the Waite Institute.

Following on a suggestion which originated in one of the State Departments, arrangements are being made for a Winter School for Soil Workers to be held at the Waite Agricultural Research Institute during the month of August, 1939. The School will be held under the auspices of the University of Adelaide and of the C.S.I.R., and will occupy not less than 10 days, beginning from August 14th.

It is not proposed to charge any fees, but all those attending must be accredited by their respective State Departments, Universities or organizations.

It is considered that the school would be of value to soil workers, not only in that personal contacts would be made and ideas interchanged, but that methods and procedures of established value can be brought to the notice of everyone. These ends will be served by a series of lectures and demonstrations following a definite plan rather than by a conference at which disconnected papers would be read.

The lecturers and demonstrators will include Professor J. A. Prescott, Dr. A. Walkley and Messrs. T. J. Marshall, C. S. Piper, C. G. Stephens, R. J. Best, T. H. Strong, J. S. Hosking and A. C. Oertel.

The following subjects have been tentatively chosen as likely to be of general interest:

Climatology and soil classification, soil survey, texture, structure, colour and water relationships of soils. Minor elements in relation to plant growth. Methods for the determination of trace elements, including chemical, spectrographic and polarographic methods. Soil acidity and lime requirement, including use of the glass electrode. The conductivity method for the determination of soluble salts and the electrometric method for the determination of soluble chlorides. Wet and dry combustion methods for the determination of soil carbon. Soil-rhizobium relations. One-day excursion through the country near Adelaide, with examination of several soil profiles.

Dr. A. Walkley, of the Waite Institute, has been appointed Secretary to the School, and he will be pleased to answer any enquiries or to receive any suggestions which would make the School as useful as possible to intending visitors.

Correction.

In the note on soil sampling methods published in the December, 1938, issue of this Journal, paragraph 3, page 233, should read as follows:

Replaceable potash figures for Mackay (in Ways—i.e. milligram equivalents per 100 grammes) were: (0.20, 0.24, 0.23, 0.17); (0.21, 0.22, 0.26, 0.27); (0.25, 0.29, 0.24, 0.25); (0.28, 0.31, 0.29, 0.27); (0.23, 0.17, 0.17, 0.21). Averages for three years: 0.24 way, 0.13 way and 0.20 way.

Book Review

FOREST PATHOLOGY, by J. S. Boyce, M.A., M.F., Ph.D.

(*Pp.* x + 600, *with* 216 *figures. New York and London: The McGraw-Hill Book Company,* 1938. *English price,* 30/-.)

Few textbooks on forest pathology have been published in English. E. E. Hubert's "Outline of Forest Pathology" (1931) is probably the only important recent predecessor of Boyce's book. Professor Boyce has discarded the idea of teaching this subject to forestry students on the orthodox basis of the taxonomic sequence of causal organisms adopted by Hubert, and arranges the parasitic diseases on the basis of the part of the tree affected. This, it is claimed, makes the book more useful to students of forestry, for whom it is primarily intended. Those preferring the taxonomic sequence will perhaps be better suited by Hubert's book, which also contains a key to forest diseases based on symptoms and a fuller discussion of the methods of diagnosis of tree diseases than that given by Boyce. Both books are almost entirely confined to North American tree diseases.

To Australian plant pathologists, the main value of such books as sources of detailed information is likely to be in relation to diseases of seedlings, shade or ornamental trees, and the rotting and staining of timber. Faulty environment at present appears to be more important than pathogenic organisms in connection with disorders of exotic conifers grown on a large scale in this country, and Boyce stresses the importance of environment and tree vigor for disease control in forest areas generally.

The production and illustration of the book are, generally speaking, in keeping with the high standard of the McGraw-Hill publications, though some of the illustrations are unduly reduced in size. The subject is introduced by brief, elementary chapters on plant and forest diseases in general, and on pathogenic fungi. Non-infectious diseases are next dealt with, and parasitic diseases are classified into those affecting seedlings, roots, foliage and stems. There is a concise summary of modern work on mycorrhiza. Fungal rots and sap stains receive detailed treatment. Each chapter is followed by numerous references.

The final chapter, on "Principles of Forest-Disease Control", is perhaps of more general interest than any other, this being the aspect in which forest pathology differs most markedly from other branches of plant pathology. The possibilities of soil amelioration and disease control are much more stringently restricted by economic considerations in the management of forests than in that of almost any other crop. Those interested who are unable to find time to read the whole book, would do well to peruse this chapter. It includes a discussion of plant quarantine, which is claimed to be more essential to forestry than to agriculture or horticulture.

W. V. Ludbrook.

Obituary

L. J. W. NEWMAN

Leslie John William Newman, F.L.S., Government Entomologist of the Department of Agriculture, Western Australia, passed away on 8th December, 1938, following a seizure. He was born on 16th February, 1878, at Sandridge, Port Melbourne.

Newman early in his career became a fervent advocate of "biological control" methods of eradicating insects. He was successful in establishing in W.Aust. the woolly aphis parasite (*Aphelinus mali*) and the green bug parasite (*Microphanurus megacephalus*), and more recently he had successfully distributed the predatory Bdellid mite (*Biscirus lapidarius*) which attacks the lucerne flea or clover springtail (*Sminthurus viridis*).

Newman's exhaustive investigations into the control of the fruit fly (*Ceratitis capitata*) led to the use of "Clensel" as an excellent lure, and still later, following South African work, sodium fluosilicate with fruit juices was shown by him to have immense local possibilities as a fruit fly bait. His studies of the life history of the codling moth have made possible the complete control of 13 adventitious introductions into W.A. of this dreaded pest of apple orchards.

The possibility of serious grasshopper outbreaks in the newer and drier wheat areas was realized by Newman from the inception of settlement in those districts, and much of his time and mental energy during the past few years were devoted to the control of grasshopper plagues. His blowfly investigations, with his assistant, Mr. John Clark, led to the development of a standard trap now widely used by farmers and pastoralists and in standard tests by the C.S.I.R., while his discovery of a successful deterrent spray for the buffalo fly (*Lyperosia exigua*) has enabled Kimberley cattle to be brought south without introducing this pest to the southern parts of the State.

Newman took a prominent part in church activities, and his unassuming character and earnestness, together with tireless devotion to his work, won for him widespread respect and esteem.

Personal Notes

Dr. J. E. Nichols, Professor of Agriculture and head of the newly established Institute of Agriculture of the University of Western Australia, tendered his resignation during December last in order to accept the post of Deputy Director of the Imperial Bureau of Animal Breeding and Genetics in Edinburgh.

Professor J. Davidson, of Adelaide, received a Research Grant from the Carnegie Corporation of New York towards the end of 1938, and left Adelaide on the 23rd February for Europe and America.

Dr. H. C. Trumble has been granted study leave by the University of Adelaide, and will leave Australia for Great Britain and America in May.

Mr. E. A. Cornish, who for some years occupied the position of Assistant Agrostologist at the Waite Institute, has been appointed Statistician to the Institute. Mr. Cornish recently worked for a period of twelve months at London University.

Mr. W. J. Webb, formerly of Dookie Agricultural College, has been appointed Technical Advisory Officer in N.S.W., of Nitrogen Fertilizers Pty. Ltd.

Mr. E. T. Edwards, Commonwealth Fund Service Fellow, has been elected an International Guest Member of the Madison (Wisconsin) Rotary Club. Early last year he was elected President of the International Club of the University of Wisconsin.

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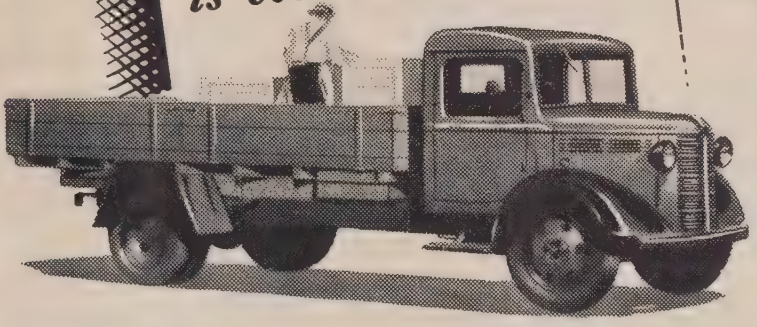

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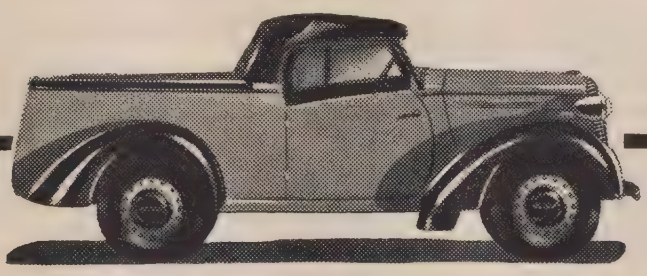

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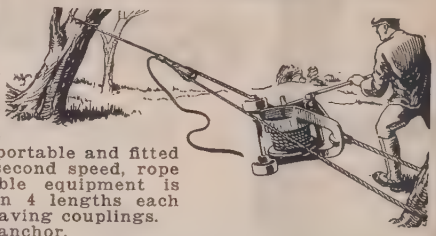

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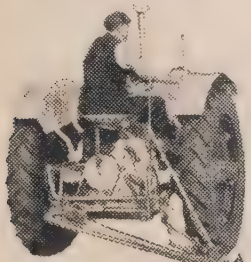

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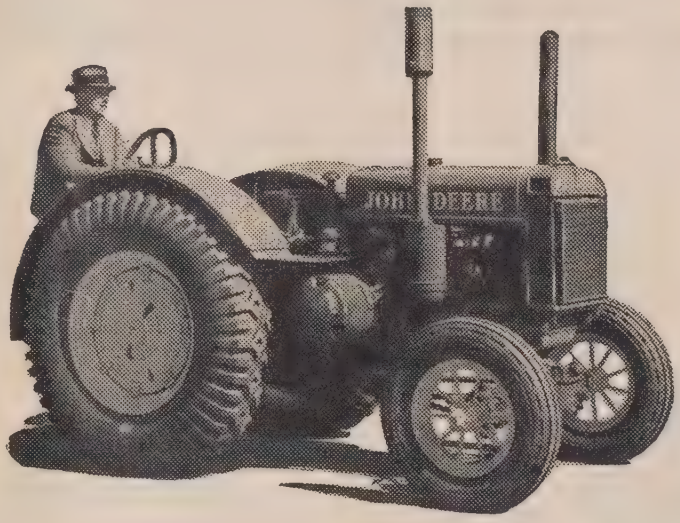

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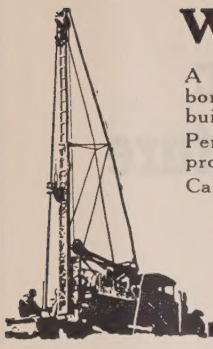

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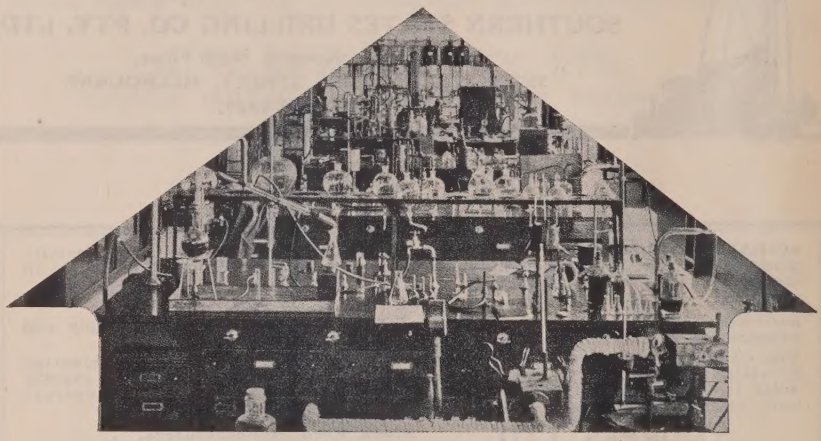

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